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BSR E1.43-201X
Entertainment Technology—Performer Flying Systems

Rig/2013-2039r6

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Entertainment Technology—Live Performer Flying Systems

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The Technical Standards Council (TSC) was established to oversee and coordinate the Technical Standards Program. Made up of individuals experienced in standards-making work from throughout our industry, the Council approves all projects undertaken and assigns them to the appropriate working group. The Technical Standards Council employs a Technical Standards Manager to coordinate the work of the Council and its working groups as well as maintain a “Standards Watch” on behalf of members. Working groups include: Control Protocols, Electrical Power, Floors, Fog and Smoke, Followspot Position, Photometrics, Rigging, and Stage Lifts.

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The Rigging Working Group, which authored this Standard, consists of a cross section of entertainment industry professionals representing a diversity of interests. PLASA is committed to developing consensus-based standards and recommended practices in an open setting.

Contents

FOREWORD

(This foreword is not part of the standard, and contains no mandatory requirements.)

There have been no specific American National Standards that cover performer flying in the entertainment industry. It should be noted that other ANSI Standards may be relevant, depending on the application and intended use. In an attempt to improve safety and standards in the industry, PLASA North America convened a series of meetings to prepare a draft standard.

It is the intention of PLASA that this standard be put forward as the basis for an American National Standard to the American National Standards Institute.

It has been assumed in the drafting of this standard that the execution of its design provisions are entrusted to appropriately qualified and experienced people, and that the fabrication and use is carried out by qualified and suitably experienced people and organizations.

This standard presents a coordinated set of rules that may serve as a guide to government and other regulatory bodies and municipal authorities responsible for the guarding and inspection of the equipment falling within its scope. The suggestions leading to accident prevention are given both as mandatory and advisory provisions; compliance with both types may be required by employers of their employees.

Safety codes and standards are intended to enhance public safety. Revisions result from committee consideration of factors such as technology advances, new data, and changing environmental and industry needs. Revisions do not imply that previous editions were inadequate.

Compliance with this Standard does not of itself confer immunity from legal obligations.

This document uses annex notes to provide additional reference information about certain specific section requirements, concepts, or intent. Subject matter with a corresponding annex note reference is identified by the note (See Annex note), and the associated reference text is found in Appendix A, Commentary, identified with the referring text section number – e.g. an annex note to section 3.2 will be identified in Appendix A, Commentary as A.3.2. The annex notes are informational only, and do not add or subtract from the mandatory requirements of this standard.

1 Scope

This document establishes a minimum level of performance parameters for the design, manufacture, use, and maintenance of performer flying systems used in the production of entertainment events. The purpose of this guidance is to achieve the adequate strength, reliability, and safety of these systems to ensure safety of the performer under all circumstances.

Performer flying systems within the scope of this standard include devices and systems supporting people or components to which people are attached, flying or suspended in the air, including acrobatic aerial acts. Situations covered by this standard pertain to any and all locations of the flight path, including over the stage or audience.

This document covers the machinery, mechanisms, and mechanical attachments used to support flying persons or ride-on flown props, including attachment to the facility/structural support down to and including the harness or other device that provides direct support for the performer, but excludes any connection that ultimately relies on the strength or ability of the Flying Performer. The use of bungee cord or other elastic lifting medium in the direct load path is outside the scope of this standard.

This document does not pertain to fall protection. This document does not apply when a performer is supported in a non-overhead suspension manner, such as lifts, elevators, turntables in stages, raked stages, treadmills in stages, or stage wagons.

Systems for flying the general public or for people engaged in non-entertainment flying effects are not included in the scope of this standard.

2 Definitions

The definitions for various participants in performer flying and their roles are defined in Section 3 *Responsibilities*.

2.1 Allowable Stress Design (ASD): A structural engineering analysis method in which service load stresses in a structure remain below a given stress limit by a specified factor. The stress limits and factors vary depending on what failure mode is being examined, such as tensile rupture or tensile yielding.

2.2 Authority Having Jurisdiction (AHJ): The organization, office, or individual responsible for approving equipment, an installation, or a procedure. (See Annex note.)

2.3 automated performer flying system: A system of mechanical components driven by machine power where two or more axes of motion are under command of a Programmable Electronic System such as a PLC or Motion Control Computer.

2.4 axis (pl. axes): A common term used to describe the combined elements that create motion in a single geometric plane. Motion can be linear or rotational and the prime mover can consist of electric, hydraulic, pneumatic, or other sources including human power in a manual system. Multiple axes can be combined to create motion of an object in more than one plane. (See Annex note.)

2.5 brake: A load securing device that is capable of stopping and securing a load.

2.6 Category 0 stop: An uncontrolled stop caused by the immediate removal of power to the machine actuators.

2.7 Category 1 stop: A controlled stop with power to the machine actuators available to achieve the stop, then removed when the stop is achieved, or after a timeout occurs.

2.8 Category 2 stop: A controlled stop with power left available to the machine actuators.

2.9 characteristic load: The maximum force applied to the performer flying system resulting from normal intended operating conditions while the system is at rest or in motion. This includes the working load limit (WLL), self-weight including that due to load carrying devices and lifting medium, and forces due to inertia and dynamics in normal use. (See Annex note.)

2.10 competent person: A person who is capable of identifying existing and predictable hazards in the workplace and who is authorized to take prompt corrective measures to eliminate them.

2.11 D/d ratio: ratio of the drum or sheave tread diameter to that of the wire rope diameter.

2.12 design factor: A ratio of the design load limit to the ultimate load carrying capacity (i.e., breaking strength) of a material or component. For ASD, the minimum design factor specified shall replace the appropriate safety factor from the design code being applied. For LRFD, the LRFD live load factor divided by the minimum design factor specified, shall replace the resistance factor from the design code being applied. (See Annex note.)

2.13 design factor against yield: A ratio of the design load limit to the yielding value of a material or component. For ASD, the minimum design factor against yield specified shall replace the appropriate safety factor from the design code being applied. For LRFD, the LRFD live load factor divided by the minimum design factor against yield specified, shall replace the resistance factor from the design code being applied. (See Annex note.)

2.14 fabricated component: A component that is custom built for an application in the performer flying system.

2.15 Factory Acceptance Test (FAT): A period of offsite testing prior to installation during which the System Supplier demonstrates that the performer flying system meets the performance and safety specifications to the extent possible during offsite testing. FAT testing requirements and performance criteria shall be agreed upon between the System Supplier and the User prior to FAT.

2.16 fleet angle: the included angle between a line representing the travel of a rope, from the groove in a sheave or drum, and a line drawn perpendicular to the rotation of the sheave or drum. (See Annex note.)

2.17 full speed: The maximum designed operating speed of a Performer Flying System. (See Annex note.)

2.18 harness: The component that is worn by the Flying Performer, which supports the Flying Performer's body weight throughout the flying routine.

2.19 lifting medium: The load carrying element, driven by the means of actuation to move the performer and any ride-on props. (See Annex note.)

2.20 limit, normal: The normal (end of travel, initial, hard) limit switch that prevents further movement in the direction of travel.

2.21 limit, software (soft): A programmed reference position that prevents further movement in the direction of travel.

2.22 limit, ultimate: The ultimate (overtravel, E-stop) limit switch that senses over-travel in the event of failure of the normal position limit.

2.23 load-bearing hardware: Purchased elements, such as fasteners, rigging components, and equipment, which are part of the load path.

2.24 load path: All contiguous mechanical elements that support the flying performer and ride-on prop, if used, up to the supporting structure. Portions of the ride-on prop that directly support the flying performer to the lifting medium shall be considered part of the load path.

2.25 Load Resistance Factor Design (LRFD): A structural engineering analysis method in which factored load stresses in a structure remain below a given stress limit. The load factors and stress limits vary depending on what type of load or combination of loads is being applied and what failure mode is being examined.

2.26 manual performer flying system: A system of mechanical components where human power alone is used to fly a performer.

2.27 mechanized performer flying system: A system of mechanical components driven by powered machinery used to fly a performer.

2.28 operating cycles: One complete series of motions consisting of a move in one direction followed by a move in the opposite direction. Programmed cues may consist of multiple operating cycles in one motion profile.

2.29 peak load: The maximum force applied to the performer flying system resulting from abnormal conditions, or irregular operation (e.g., effects of emergency stops, uncontrolled stops, drive electronics or power failure, stalling of the actuation equipment, extreme environmental conditions).

2.30 performer peak load: The maximum force applied to the performer resulting from abnormal conditions, or irregular operation (e.g., effects of emergency stops, uncontrolled stops, drive electronics or power failure, stalling of the actuation equipment, extreme environmental conditions).

2.31 performer flying system: A system of components specifically designed to transport a performer through the air. The performer flying system includes the attachment to the facility/structural support down to and including the harness or other device that provides direct support for the performer.

2.32 purchased component: A serially manufactured, commercially available component.

2.33 qualified person: A person who, by possession of a recognized degree or certificate of professional standing, or who by extensive knowledge, training, and experience, has successfully demonstrated the ability to solve problems relating to the subject matter and work.

2.34 quick-connect hardware: A component that is used to quickly connect or disconnect the performer or ride-on prop to the lifting medium.

2.35 rescue: The prompt return of the Flying Performer to a safe location and disconnecting from the performer flying system in the event of Flying Performer's danger or distress.

2.36 rescue plan: The operational procedures used to perform a rescue.

2.37 rescue system: A system of components used to land a flown performer in a safe location in case of a flying system malfunction or a medical emergency.

2.38 ride-on prop: Scenic element supported by the performer flying system that bears the weight of the performer.

2.39 rigid lifting medium: Truss, structural shapes, arms, fabricated components, etc. used to directly move the performer and any ride-on props.

2.40 risk: Combination of the probability of occurrence of harm and severity of that harm.

2.41 risk assessment (RA): The process of identifying, evaluating, and quantifying the potentially hazardous conditions, severity, and probability of occurrence of harm.

2.42 risk reduction (RR): Mitigation of risk created by hazardous conditions.

2.43 risk assessment / risk reduction (RA/RR): The cyclical process of identifying risk, mitigating risk, evaluation of residual risk, and repeating the process until the risk has been reduced to an acceptable level.

2.44 Site Acceptance Test (SAT): A final step in the installation during which the System Supplier demonstrates to the User by testing that the performer flying system meets the performance and safety specifications. SAT performance criteria shall be agreed upon between the System Supplier and the User prior to SAT.

2.45 shall: Indicates that the rule is mandatory and must be followed.

2.46 should: Indicates that the rule is a recommendation, the advisability of which depends on the facts and conditions in each situation.

2.47 tensioned cable track: Flexible medium statically suspended and tensioned between two points to form a catenary-curved track.

2.48 ultimate load carrying capacity: The maximum load a component may support without fracture, buckling or crushing as determined by nationally recognized construction standards appropriate for the given material. (See Annex note.)

2.49 working load limit (WLL): The maximum weight as defined by the Flying System Designer that a User is allowed to apply to a lifting medium in the performer flying system.

3 Responsibilities

3.1 Intent

The intent of this section is to define the roles and associated responsibilities involved in performer flying effects. There shall be a competent person or persons responsible for the following aspects of the performer flying, unless otherwise noted. A person may take on several of these roles depending on the nature of the flying effect. (See Annex note.)

3.2 Creative Designer

Person who choreographs the flying performance sequences and related visual conception. This person is not responsible for the design of the performer flying system. This person shall coordinate the choreography with the Flying Safety Supervisor and overall show technical director to ensure safe operation for all involved persons.

3.3 First Aid Attendant

Competent person trained in first aid and CPR, in charge of first respondent treatment of a Flying Performer after a rescue.

3.4 Flying System Designer

Qualified person who designs the technical performer flying system to satisfy the intent of the creative design and who is responsible for validating the safety and integrity of the performer flying system design.

3.5 Flight Sequence Programmer

Competent person responsible for programming the flight cue sequences of automated performer flying systems.

3.6 Flying Operator

A competent person responsible for operation of the performer flying system. In a complex fly effect, there may be multiple Flying Operators with coordinated function.

3.7 Flying Performer

Person who is flown as part of the show performance in view of the audience.

3.8 Flying Safety Supervisor

Qualified person responsible for overall safety of the performer flying system, including training, maintenance, inspections, testing, queuing, choreography and confirming suitability of Flying Performers for intended flight.

3.9 Flying Supervisor

Competent person responsible for operational safety and wellbeing of the Flying Performers. (See Annex note.)

3.10 Incident Commander

Competent person responsible for directing emergency crew and rescue operations during an emergency or rescue situation.

3.11 Observer

Competent person responsible for observing that the Spotter has correctly performed his/her duties. The Observer may also be responsible for communicating with the Flying Operator(s) or Stage Manager, if stipulated by the Flying Safety Supervisor. The Observer role is <u>not</u> required unless stipulated by the Flying Safety Supervisor or by the Authority Having Jurisdiction.

3.12 Professional Engineer

Licensed engineering professional who provides engineering evaluations supporting the performer flying system design. The Professional Engineer role is *not* required unless stipulated by the performer Flying System Designer or by the Authority Having Jurisdiction.

3.13 Rescue Rigger

Qualified person who is responsible for understanding the rescue plan and performing rescue operations under the direction of the Incident Commander.

3.14 Spotter

Competent person responsible for:

3.14.1 Placing and checking the harness on the Flying Performer.

3.14.2 Attaching and removing the quick connect hardware.

3.14.3 Assisting the Flying Performer with launch and landing.

3.14.4 Assisting the Flying Performer with held props, costumes, or ride-on props.

3.14.5 Communicating with Flying Operator(s) or Flying Supervisor, unless the Flying Supervisor stipulates that such communication shall be done by an Observer.

3.14.6 Observing that conditions are suitable for the Flying Performer to fly.

3.14.7 Determining that the Flying Performer is ready for flight.

3.15 Stage Manager

A competent person who manages the overall performance during the show, and who shall coordinate with the Flying Operators and Spotters in cuing Flying Performer flight with other show cues.

3.16 System Installer

The company or qualified person responsible for the installation of the performer flying system, complying with the requirements of the Flying System Designer, and System Supplier.

3.17 System Supplier

Person or company who integrates and assembles the performer flying system and supplies that performer flying system to a production for rent or to an end user as a sale, complying with the requirements of the Flying System Designer.

3.18 User

Person or company that manages and is ultimately responsible for the use of the performer flying system for the intended flying effect for the live performance. In the context of the performer flying system, the User manages the people responsible for maintaining and operating the system, including Flying Operators, Stage Manager, Technicians, Flying Safety Supervisor, Flying Supervisor, Flying Performers, Spotters, Rescue Riggers, Incident Commander, and Observers. The User shall keep a written record of the person or persons responsible for each role herein, and shall update this record whenever there is a personnel change.

4 Design and Engineering

4.1 Intent

The intent of this section is to establish requirements for the design and engineering of performer flying system and system components. Variations on the design requirements shall be permitted pursuant to RA/RR, or review and approval by a Professional Engineer.

4.2 Design

4.2.1 The following standards and documents shall be used in the design of the performer flying system and shall be dependent on the intended conditions of use.

4.2.1.1 ANSI E1.2-2012 “Entertainment Technology – Design, Manufacture and Use of Aluminum Trusses and Towers”

4.2.1.2 ANSI E1.4-2014 “Entertainment Technology – Manual Counterweight Rigging Systems”

4.2.1.3 ANSI E1.6-1-2012 “Entertainment Technology – Powered Hoist Systems”

4.2.1.4 NFPA 70: National Electrical Code, 2011 edition

4.2.1.5 NFPA 79: Electrical Standard for Industrial Machinery, 2012 Edition

4.2.1.6 AWS D1.1-10 Structural Welding Code – Steel

4.2.1.7 AWS D1.2-08 Structural Welding Code - Aluminum

4.2.1.8 Wire Rope User’s Manual, 4nd Edition – Wire Rope Technical Board

4.2.2 The following documents are referenced, and shall be used as applicable to the performer flying system. For dated references, only the edition cited applies. For undated references, the latest edition of the reference document, including any amendments, shall apply.

4.2.2.1 ASCE/SEI 7-10, “Minimum Design Loads for Building and Other Structures”

4.2.2.2 ASCE 19-10 “Structural Applications of Steel Cables for Buildings”

4.2.2.3 ADM1-10 “Aluminum Design Manual - Specifications for Aluminum Structures”

4.2.2.4 AISC 360-10 "Specifications for Structural Steel Buildings”

4.2.2.5 AISC 303-10 "Code of Standard Practice for Steel Buildings and Bridges”

4.2.2.6 American Institute of Steel Construction, “Manual of Steel Construction,” 14th Edition

4.2.2.7 ANSI / ASSE A359.1-2007 “Safety Requirements for Personal Fall Arrest Systems, Subsystems and Components,” Version 3

4.2.2.8 ANSI / ASSE A359.4-2013 “Safety Requirements for Assisted-Rescue and Self-Rescue Systems, Subsystems and Components,” Version 3

4.2.2.9 NFPA 1983-2012: Standard on Life Safety Rope and Equipment for Emergency Services

4.2.3 All conditions of use in the design shall be explicitly outlined in the system design documentation.

4.2.4 Strength

4.2.4.1 The strength of individual components or assemblies can be established using either Load Resistance Factor Design (LRFD) or Allowable Stress Design (ASD) methods, or by physical testing in accordance with a recognized national standard and referenced in engineering documentation. (See Annex note.)

4.2.4.2 Design factors shall be used as specified herein for different parts of the performer flying system. (See Annex note.)

4.2.5 Manual Flying Systems

Manual performer flying systems shall be designed to incorporate all of the requirements of this standard, with the exception of Section 4.10 Electromechanical Actuation.

4.2.6 Performer Flying System design

4.2.6.1 The performer flying system shall be designed by a qualified person.

4.2.6.2 Flying System Designer shall use a process of RA/RR during the design phase to mitigate hazards.

4.2.6.3 Flying System Designer shall promote redundancy in design to mitigate single point failure and cascading failures. In situations where single points or cascading failure points of support are unavoidable, the Flying System Designer shall use a suitably conservative design factor to mitigate risks based on RA/RR. (See Annex note.)

4.2.6.4 The Flying System Designer shall determine the anticipated operating cycles for the flying system.

4.2.6.5 The design shall include provisions for inspections, testing, assembly, installation, operational use, and rescue procedures.

4.2.6.6 Where the performer flying system is attached to rigging equipment deemed “Not suitable for flying people” by the manufacturer, the Flying System Designer shall use RA/RR to determine appropriate use and takes on full responsibility for this use.

4.2.7 End stops for traveler track

4.2.7.1 The system design shall include full speed end of motion physical stops past the ultimate limit switches (if applicable) for moving mechanical elements.

4.2.7.2 The end stops shall be designed to take a full speed full load impact without causing catastrophic mechanical or structural failures that would result in an unsafe condition, unless a 'safe' slow zone mechanism is implemented that precludes the ability for the travelling component to impact the end stop at full speed and/or full load. (See Annex note.)

4.2.7.3 A risk assessment shall be conducted to assess end of travel protection for the Flying Performer.

4.2.8 Flying System Design Details

4.2.8.1 D/d ratio shall be determined by the flexible medium manufacturer’s recommendation.

4.2.8.2 Fleet angle shall not exceed 2 degrees for grooved drums and 1.5 degrees for smooth drums, either side of centerline.

4.2.8.3 Sheave blocks and drums shall be designed or selected as to prevent the lifting medium from coming out of the groove.

4.2.8.4 The grooves in sheaves and drums shall be properly sized for the lifting medium being used. (See Annex note.)

4.2.8.5 The performer flying system design shall accommodate pendulum swings without exceeding fleet angle specifications.

4.2.8.6 Except where permitted by the AHJ and also subject to RA/RR, flying performers’ flight paths shall not bring the performer, ride-on props, or equipment within the reach of members of the public or into unintended contact with other show personnel.

4.2.9 Component selection and design

4.2.9.1 Purchased components

4.2.9.1.1 Selection of purchased components shall be based on performer flying system requirements.

4.2.9.1.2 Selection of purchased components shall be based on evaluation of component manufacturer’s technical data and written guidelines.

4.2.9.1.3 Purchased components selected shall be supplied with a visible load rating mark from the manufacturer or certification of its load rating by the manufacturer, unless components meet the specifications of Section 4.2.9.1.4.

4.2.9.1.4 The use of a purchased component without a visible load rating mark or certification of its load rating or strength shall be allowed only if approved by a Professional Engineer or validated by testing performed under the direction of a qualified person.

4.2.9.1.5 All fasteners shall be non-malleable, steel construction, unless otherwise determined by RA/RR.

4.2.9.1.6 Open end terminations shall not be used in the performer flying system. (See Annex note.)

4.2.9.2 Fabricated components

Fabricated Components shall be evaluated and approved by the Flying System Designer or validated by testing performed under the direction of a qualified person.

4.3 Analysis

4.3.1 Engineering

4.3.1.1 The analysis of structures for the intended load conditions shall be performed by calculation, modeling, physical testing, or combination of these methods.

4.3.1.2 The analysis shall consider the governing combination, application, and configuration of loads and effects within the use guidelines.

4.3.1.3 Characteristic loads and peak loads shall be considered in determining the loads applied to the facility structure. (See Section 4.11.1 Facility Anchorage.)

4.3.2 Risk assessment and risk reduction (RA/RR)

4.3.2.1 Risk assessment (RA) and risk reduction (RR) shall be performed by a group of two or more competent persons or by at least one qualified person. (See Annex note.)

4.3.2.2 RA/RR shall be performed for performer flying systems throughout conceptualization, design, fabrication, installation, and testing.

4.3.2.3 RA/RR shall be performed for new system designs to evaluate strength and appropriateness of materials and components.

4.3.2.4 RA/RR for machine powered systems shall follow the procedures described in E1.6-1-2012, Section 4.

4.3.2.5 RA/RR shall be performed for each installation of stock systems to evaluate appropriateness of the equipment for the intended use.

4.3.2.6 A written risk assessment shall be recorded by the group or individual performing the assessment.

4.3.2.7 A written risk assessment shall be made available by request. The report shall contain details describing:

4.3.2.7.1 Definitions of the limits of use

4.3.2.7.2 Identification of the hazards associated with use.

4.3.2.7.3 Identification of hazards associated with reasonably foreseeable misuse

4.3.2.7.4 Classification of the risk in terms of severity and probability of harm.

4.3.2.7.5 Methods used to mitigate the risks

4.3.2.7.6 Date of completion

4.3.2.8 The group or person performing the risk assessment and risk reduction shall determine the acceptable level of residual risk.

4.3.2.9 The risk assessment shall identify all possible ways of triggering emergency stops that are initiated by the Flying Operator, other technicians, Flying Performer, or control system and the associated response of the performer flying system. Forces from these emergency stops fall into the category of peak loads.

4.3.2.10 The risk assessment shall identify potential peak loads and likelihood of their occurring during the anticipated life of the performer flying system.

4.3.2.11 The risk assessment shall consider the proximity and clearances of members of the public and show personnel to the flying performers during normal operations, all stop conditions, and during rescue operations.

4.3.3 Loading conditions

4.3.3.1 Dynamic

4.3.3.1.1 Flying System Designer shall evaluate effects of acceleration and deceleration in peak load calculations as applied to the performer flying system and Flying Performer.

4.3.3.1.2 The Flying Performer shall confirm that he/she has the physical capability to withstand performer peak loads imposed on the body by the harness.

4.3.3.1.3 Performer flying systems shall be designed such that loads imposed on the Flying Performer by the harness (characteristic and peak loads) are within the limits specified in the following graphs (Figures 1 through 5) based on definitions of Physiological Accelerations Systems in Table 1. [Graphs derived from ASTM F2291 “Standard Practice for Design of Amusement Rides and Devices” and NASA Memorandum “Human Tolerance to Rapidly Applied Accelerations” by A. Martin Eiband, June 1959.] The graphs indicate that acceleration/deceleration of 2.8G on the Flying Performer is allowed for a maximum duration of 0.2 seconds without regard to Flying Performer orientation relative to motion. (See Annex note.)

TABLE 1: Physiological Acceleration Systems

Vernacular Description	Pictorial Description	Verbal Definition	Descriptive Terms	AGARD Symbol	Heart Displacement	Other Terms	Other Terms
Eyeballs in		A force applied to the posterior part of the trunk, acting forward with respect to the subject and perpendicular to the mean spine produces a forward acceleration.	Forward acceleration or forward acting force	$+G_x$	Moves toward back	Forward Acceleration	Transverse A-P G Supine G Chest to back G Sternumward
Eyeballs out		A force applied to the anterior part of the trunk, acting backward with respect to the subject and perpendicular to the mean spine produces a backward acceleration.	Backward acceleration or backward acting force	$-G_x$	Moves toward front	Backward Acceleration	Transverse P-A G Prone G Back to chest G Spineward
Eyeballs left		A force applied to the left surface of the subject's body, acting in a rightward direction and essentially perpendicular to the subject's mean spine produces a rightward acceleration.	Rightward acceleration or rightward acting force	$+G_y$	Moves toward left	Right Lateral Acceleration	Left lateral G
Eyeballs right		A force applied to the right surface of the subject's body, acting in a leftward direction and essentially perpendicular to the subject's mean spine produces a leftward acceleration.	Leftward acceleration or leftward acting force	$-G_y$	Moves toward right	Left Lateral Acceleration	Right lateral G
Eyeballs down		A force applied to the buttocks, thighs, and/or feet, acting in a headward direction with respect to the subject and essentially parallel to the subject's mean spine produces a headward acceleration.	Headward acceleration or headward acting force	$+G_z$	Moves toward feet	Headward Acceleration	Positive G Headward
Eyeballs up		A force applied to the shoulders, thighs, and feet acting in a tailward direction with respect to the subject and essentially parallel to the subject's mean spine produces a tailward acceleration.	Tailward acceleration or tailward acting force	$-G_z$	Moves toward head	Tailward Acceleration	Negative G Tailward

Modified from Table 41: Physiological Acceleration Systems in Hugh W. Randel's *Aerospace Medicine, 2nd ed.*,
based on table compiled by Gerard J. Pesman in Dictionary of Technical Terms for Aerospace Use, edited by W.H. Allen, NASA SP-7, Washington, D.C., 1965

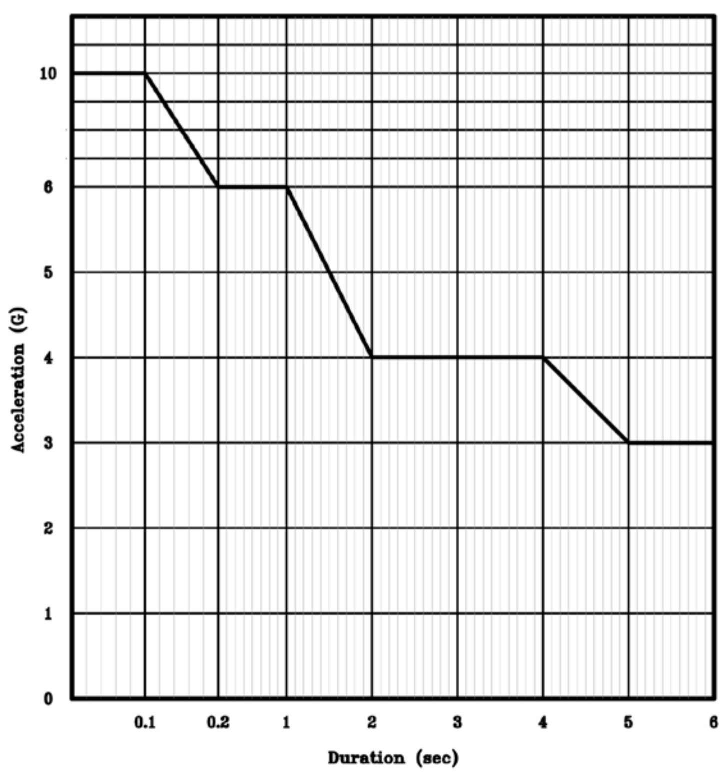


FIGURE 1: Time Duration Limits for Eyeballs In ($+G_x$)

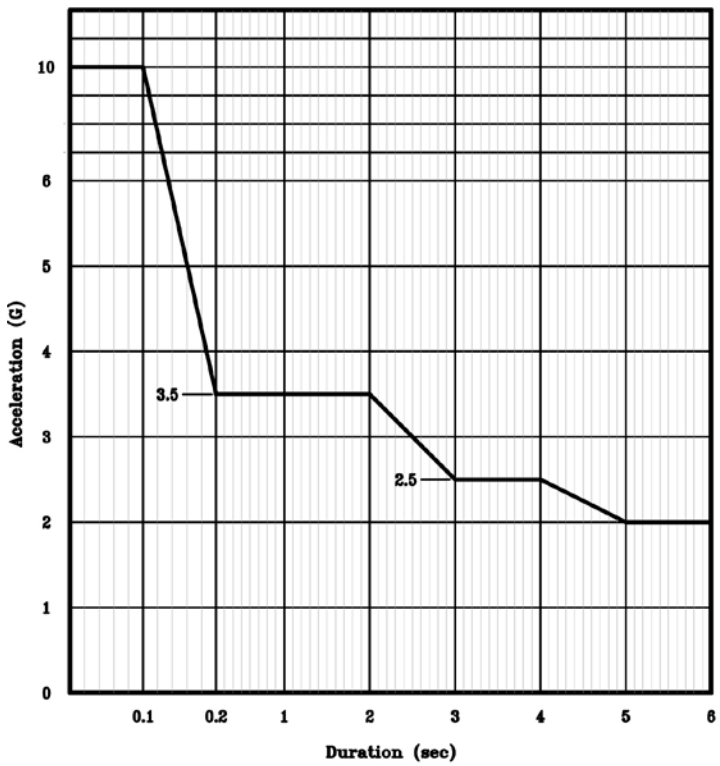


FIGURE 2: Time Duration Limits for Eyeballs Out ($-G_x$)

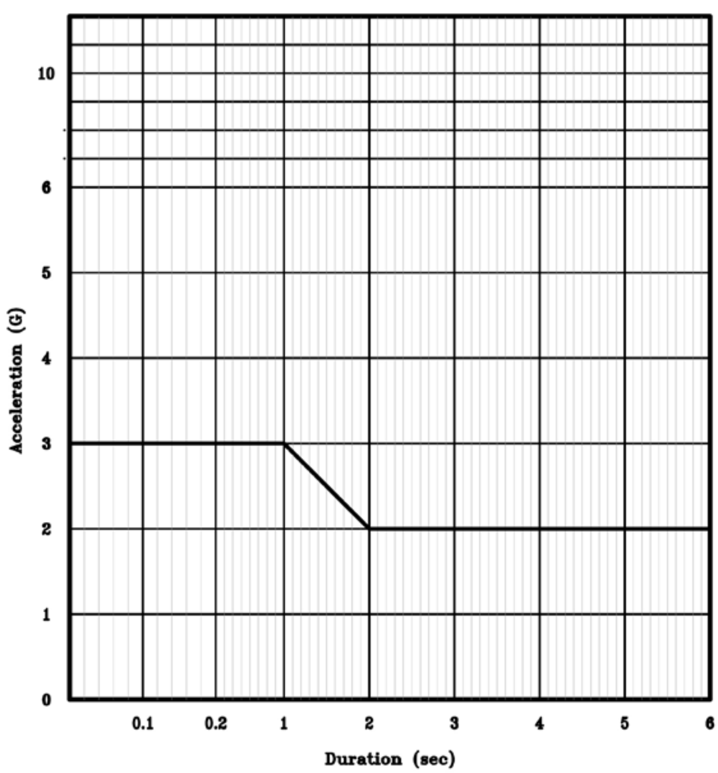


FIGURE 3: Time Duration Limits for Eyeballs Left or Right ($\pm G_Y$)

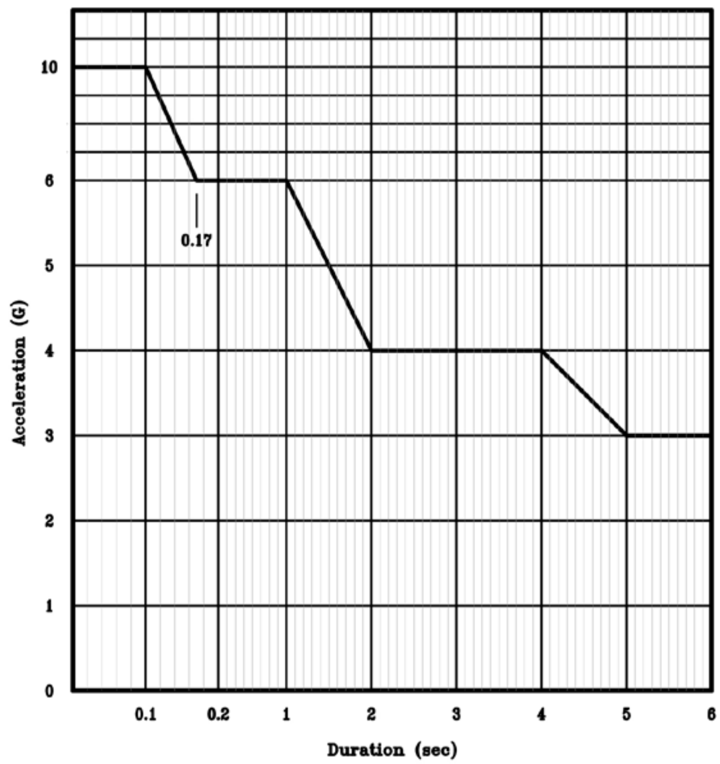


FIGURE 4: Time Duration Limits for Eyeballs Down (+G_Z)

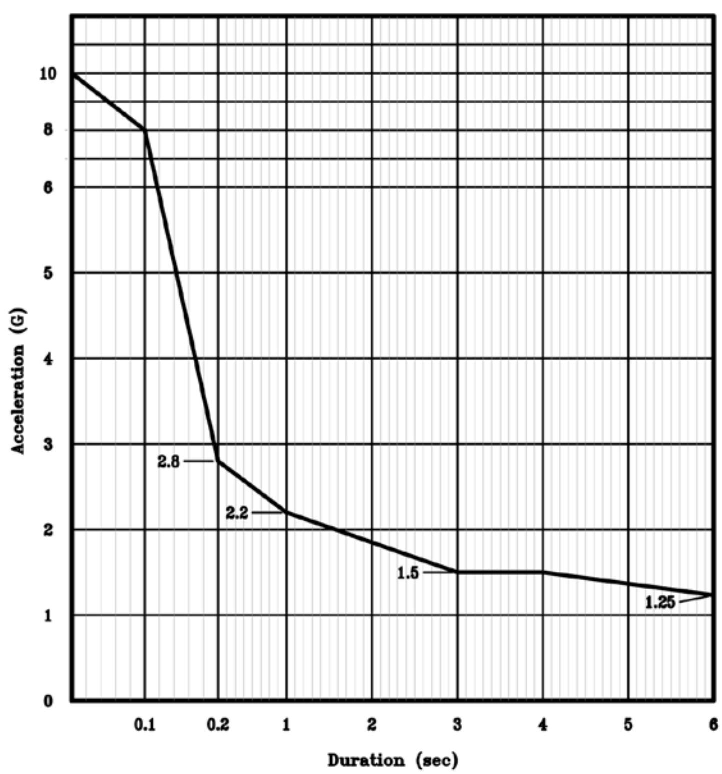


FIGURE 5: Time Duration Limits for Eyeballs Up (-G_Z)

4.3.3.1.4 For multiple axis (3D) performer flight systems, loads imposed on the Flying Performer by the harness shall comply with Figures 11-18 of ASTM F2291 “Allowable Combined Magnitude of (two or three axes) Accelerations.”

4.3.3.1.5 Higher performer loads than those specified in Section 4.3.4.3 may be permitted for specialty acts using properly trained Flying Performers, only if validated by RA/RR.

4.3.3.1.6 The surface area pressure of the harness resisting the performer load shall be evaluated during harness design and selection in order to avoid performer discomfort when subjected to characteristic loads and to avoid performer injury when subjected to peak loads. (See Annex note.)

4.3.3.1.7 Flying System Designer shall evaluate effects of peak load tension on tensioned cable track attachments points.

4.3.3.1.8 Peak load design factors included in this document pertain to all potential types of peak loads. (See Annex note.)

4.3.3.2 Tensioned Cable Track

4.3.3.2.1 The Flying System Designer shall evaluate self-weight, characteristic and peak loads, and environmental variables imposed on tensioned cable tracks.

4.3.3.2.2 The Flying System Designer shall determine the required design factor for tensioned cable tracks for each performer flying system. (See Annex note.)

4.3.3.3 Environmental

4.3.3.3.1 The Flying System Designer shall evaluate and consider relevant environmental variables, such as wind, snow, ice, seismic, corrosion, temperature, and rain.

4.3.3.3.2 The Flying System Designer shall evaluate and consider additional prevailing forces for mobile theatre application, such as ships, vessel, floats, and vehicles.

4.4 Engineering documentation

4.4.1 Engineering drawings of the structural, mechanical, and electrical elements, and general arrangement drawings of the performer flying system, shall be developed and maintained by the Owner.

4.4.2 Engineering drawings shall include the following:

4.4.2.1 Dimensions

4.4.2.2 Components

4.4.2.3 Subassemblies

4.4.2.4 Material types

4.4.2.5 Fastener types, specifications, and torque values

4.4.2.6 Weld sizes and types

4.4.3 Engineering calculations, design notes, and/or test results shall be developed and maintained.

4.4.4 The documentation package shall contain definitive statements about the operating limits of the system including physical forces, range of motion, speeds, and accelerations.

4.4.5 The documentation package shall clearly indicate where the Performer Flying System ends and how it interfaces with the support structure, including loads imparted to the support structure.

4.5 Personal flying equipment

4.5.1 Harnesses

4.5.1.1 The flying harness shall be designed or selected by a qualified person solely for the specific purpose of creating flying effects in an entertainment performance environment.

4.5.1.2 Selection and design of the harness shall consider the suitability of the support provided by the harness as it relates to the intended flight body position (e.g., upright, lying down, prone or side position, inverted) and physical capabilities of the Flying Performer. (See Annex note.)

4.5.1.3 The maximum period of time the Flying Performer is expected to be supported by the harness shall be considered in the selection and design of harnesses and accessories (leg straps, stirrups, chairs, etc.) (See Annex note.)

4.5.1.4 The harness shall have a permanently attached label that includes the following information: (See Annex note.)

4.5.1.4.1 Manufacturer and contact information

4.5.1.4.2 Working Load Limit

4.5.1.4.3 Date of manufacture

4.5.1.4.4 Serial number

4.5.1.4.5 Applicable Warnings

4.5.1.4.6 Reference to User Manual

4.5.1.5 Harness Manufacturer shall provide the following:

4.5.1.5.1 Inspection criteria

4.5.1.5.2 Factory Quality Control Documentation

4.5.1.6 Performer flying harnesses shall be designed and selected with a minimum design factor of 10X WLL, 6X characteristic load and 3X peak load.

4.5.1.6.1 When lower design factors are used in the design of harnesses, the label shall clearly indicate usage limitations. Such harnesses may only be used if deemed acceptable by a qualified person based on RA/RR.

4.5.1.7 Connections to the lifting medium shall be secure under both load and slack conditions.

4.5.1.8 The application of costumes, paint, or any additional material to the harness shall not compromise the strength of the material, interfere with its operation, or impede the inspection of the

stitching and connection hardware. Any application or addition shall be approved by manufacturer or Flying Safety Supervisor.

4.5.2 Ride-on props

4.5.2.1 Any flying vessels, platforms, or props shall be designed by a qualified person.

4.5.2.2 Ride-on props shall be designed to comply with Section 4.3.3 Loading Conditions.

4.5.2.3 Ride-on props shall be attached in a manner that in the event of a failure of the prop support lines the prop does not become supported by the Flying Performer, the Flying Performer's harness, or any point along the load path to the Flying Performer.

4.5.2.4 All Flying Performers riding on or in flying vessels, platforms, or props shall be tethered directly to the load path.

4.5.2.5 Strength design factors (See Annex note.)

4.5.2.5.1 Elements in the load path that are subject to single point or cascading failures shall be designed using the same design factors as rigid lifting medium (See Section 4.8.4.3).

4.5.2.5.2 Elements in the load path that are not subject to single point or cascading failures shall be designed using the same design factors as static load bearing components (See Section 4.9).

4.6 Quick-connect hardware

4.6.1 All quick-connect hardware shall be designed such that its default state is closed / locked.

4.6.2 All quick-connect hardware shall require at least two actions to open/unlock. These actions can be simultaneous or sequential. The number of required actions shall be determined by RA/RR.

4.6.3 Quick-connect hardware shall be selected to prevent unintended disconnection.

4.6.4 Purchased hardware used for quick-connect hardware shall bear a load rating that is permanently marked on the hardware.

4.6.5 Quick-connect hardware shall be designed and selected with a minimum design factor of 10X WLL, 6X characteristic load and 3X peak load. In situations where the characteristic loads are confirmed by documented empirical testing data or by engineering calculations prepared by a qualified person, the Flying System Designer is permitted to reduce the WLL design factor to 8X.

4.6.6 When multiple quick-connect hardware is used to fly a Flying Performer or Ride-on prop, in the event of a failure of one quick-connect hardware, the remaining hardware shall be capable of safely supporting the load. Reduced safety factors may be used if determined by the Flying System Designer based on RA/RR.

4.6.7 Custom quick-connect hardware designs shall be reviewed and approved by a Professional Engineer, or validated through testing as described in 5.6 Factory Acceptance Testing.

4.7 Other load-bearing hardware

4.7.1 All load-bearing hardware shall be selected to prevent unintended disconnection.

4.7.2 Purchased load-bearing hardware shall either have a marked load rating, grade rating, or have an identifying marking that correspond to catalog listed ratings, or be supplied with documentation of its strength, working load limit, or ultimate breaking strength.

4.7.3 Load-bearing hardware shall be designed and selected with a minimum design factor of 10X WLL, 6X characteristic load and 3X peak load. In situations where the characteristic loads are confirmed by documented empirical testing data or by engineering calculations prepared by a qualified person, the Flying System Designer is permitted to reduce the WLL design factor to 8X.

4.8 Lifting medium

Lifting medium may take the form of steel wire or synthetic rope(s), synthetic or metallic webbing or band(s), physical structures such as arms and trusses, or other means of supporting and moving the Flying Performer.

4.8.1 Material

Material for the lifting medium shall be chosen by a qualified person based on the Performer flying system's physical and performance requirements, and best engineering practices.

4.8.1.1 The lifting medium shall be of sufficient strength to withstand the expected characteristic and peak loads imposed by operation of the Performer flying system. The strength shall be determined after the application of the appropriate de-rating factors if applicable.

4.8.1.2 The lifting media selection shall consider the anticipated number of operating cycles and inspection and maintenance frequency.

4.8.1.3 The material chosen for the lifting medium shall be furnished with mill or manufacturers certification documents detailing the base materials used in manufacturing, the origin and location of manufacture, and quality control and quality assurance testing methods and results. These documents shall be included in the documentation package maintained by the Owner.

4.8.2 Terminations and Swivels

The lifting medium shall be able to be securely terminated at both ends.

4.8.2.1 All terminations shall be made in accordance with manufacturer's specifications. De-rated values of the lifting media due to terminations shall be considered in determining design factors and related strength data.

4.8.2.2 The use of swivels shall be in accordance with the rope manufacturer's recommendations and de-rated values of the lifting media due to the use of swivels shall be considered when determining design factors and related strength data. (See Annex note.)

4.8.3 Manufacturing treatments

4.8.3.1 Strength and endurance reductions caused by finishes or coatings applied to lifting medium shall be considered.

4.8.3.2 De-rating factors for welding, heat treatments, bending, or other processes that affect the strength of the base material shall be applied prior to determining the final design factor.

4.8.4 Strength design factors

Lifting medium shall be sized to meet the following design factors:

4.8.4.1 Flexible lifting medium

Flexible lifting medium (e.g., rope, chain, band, webbing) shall be designed with a minimum design factor of 10X WLL, 6X characteristic load and 3X peak load. In situations where the characteristic loads are confirmed by documented empirical testing data or by engineering calculations prepared by a qualified person, the Flying System Designer is permitted to reduce the WLL design factor to 8X.

4.8.4.2 In-view flexible lifting medium

In situations where it is desirable to minimize the visibility of the flexible lifting medium from the audience perspective, and the lifting medium does not travel over sheaves, drums, or other objects, lesser design factors may be used as determined by RA/RR, but not less than 5X WLL, 3X characteristic load and 1.5X peak load. (See Annex note.)

4.8.4.3 Rigid lifting medium

4.8.4.3.1 Rigid lifting medium shall be designed with a minimum design factor of 8.33X WLL, 5X characteristic load and 2.5X peak load. In situations where the characteristic loads are confirmed by documented empirical testing data or by engineering calculations prepared by a qualified person, the Flying System Designer is permitted to reduce the WLL design factor to 6.67X.

4.8.4.3.2 Where design code equations include material yield, rigid lifting medium shall be designed with a minimum design factor against yield of 3X characteristic load and 1.5X peak load.

4.8.5 Multiple-lifting medium

When multiple lifting medium are used to fly a performer or Ride-on prop, in the event of a failure of one lifting medium element, the remaining lifting medium shall be capable of safely supporting the load. Reduced design factors may be used if determined by the Flying System Designer based on RA/RR.

4.8.6 Fatigue factors

The design and selection of the lifting medium shall consider the following fatigue factors when making material selections: (See Annex note.)

4.8.7 Cycles

Use the number of bend and loading cycles to determine the expected service life of lifting medium elements. Service life is determined by multiplying the number of bending/loading cycles on the lifting medium during each operation by the anticipated total number of operations, which include testing, rehearsal, maintenance, and performance.

4.8.8 Diameter and quantity of sheaves and rollers

In the case of flexible lifting medium, the quantity and relative position of the sheaves and rollers in the performer flying system shall be used to determine the number of bending fatigue cycles on the lifting medium during each operation. The number of bending fatigue cycles, the number of changes bend direction, and the D/d ratios shall be considered when determining the effective service life.

4.8.9 Stress range

The stress range (differential loads) experienced by the lifting medium shall be determined in order to establish the expected service life.

4.8.10 Environment

The physical environment in which the performer flying system will be installed and utilized shall be considered for exposure to weather, corrosive materials, ultraviolet radiation, humidity, salt air, and other elements that may influence the service life or integrity of the lifting medium.

4.8.11 Wear or abrasion points

Idlers, glide plates, or other points of wear or abrasion to the lifting medium, as well as fleet angle, sheave alignment, groove profile, shall .be considered when determining its effective service life.

4.8.12 Inspection and replacement

The performer flying system design shall accommodate frequent and complete inspection of the full length of the lifting medium and its termination points. The performer flying system design shall accommodate full replacement of the lifting medium at regular intervals as determined by the Flying System Designer and detailed in the Maintenance and Inspection procedures.

4.9 Static Load Bearing Components (See Annex note.)

4.9.1 Strength

4.9.1.1 Static load bearing components shall be designed with a minimum design factor of 6.67X WLL, 4X characteristic load and 2X peak load. In situations where the characteristic loads are confirmed by documented empirical testing data or by engineering calculations prepared by a qualified person, the Flying System Designer is permitted to reduce the WLL design factor to 5.33X.

4.9.1.2 Where design code equations include material yield, static load bearing components shall be designed with a minimum design factor against yield of 2.5X characteristic load and 1.25X peak load.

4.9.2 All welds shall comply with current American Welding Society standards.

4.9.3 Deflection of all static load bearing components shall not be detrimental to equipment operation.

4.10 Electromechanical Actuation

4.10.1 Mechanical

Mechanized performer flying systems shall incorporate all aspects of mechanical requirements herein, unless otherwise determined by RA/RR.

4.10.1.1 All motorized hoist systems shall conform to ANSI E1.6-1-2012, “Entertainment Technology – Powered Hoist Systems.”

4.10.1.2 The maximum force that can be produced by the electromechanical actuator shall be evaluated as part of the process to determine peak loads in the performer flying system.

4.10.1.3 If an electromechanical actuator is selected that is capable of producing a force that would overload any of the elements in the load path based on the required design factor, then the Flying System Designer shall incorporate measures to reduce the maximum force from the actuator on the components in the load path so that the required design factors are satisfied.

4.10.1.4 The following sections address additional requirements or exceptions to the referenced standards. In the case of conflicts between the referenced standards and this document, this document shall take precedence.

4.10.2 Load-securing devices

4.10.2.1 As per E1.6-1 2012 Section 6.2.3.1, hoists shall include at least two independently functioning load-securing devices.

4.10.2.2 The purpose of the load securing devices shall be to independently secure the load at any position. One device shall be directly coupled to the termination point of the lifting medium at the drive mechanism, such as a winch drum or chain wheel. The second load securing device may be located anywhere in the power transmission system. (See Annex note.)

4.10.2.3 A gearbox alone shall not be considered as a load securing device.

4.10.2.4 Each load securing device shall be sized to hold at least 1.25 X WLL. The load securing system shall be designed to stop the WLL during a Category 0 stop, at full speed in both directions.

4.10.2.5 For machines where the drum or other termination point of the lifting medium is driven by a chain, belt or otherwise not directly driven by a gearbox or other prime mover, measures shall be taken to ensure that any failure of the drive chain (belt, etc.) shall cause the load securing device to engage.

4.10.2.6 It shall be possible to release each of the load-securing devices without relying on facility power service by utilizing manual devices and/or readily available, locally stored power sources (such as batteries, generators, etc.). Such releases shall be achievable in a period of time that does not place the Flying Performer at risk.

4.10.2.7 It shall be possible to adjust one of the load-securing devices without relying on facility power service, in order to transition from secured load to controlled movement of the Flying Performer load to facilitate rescue operations.

4.10.2.8 If readily available battery back-up or uninterruptable power supply (UPS) are relied upon to release and/or control the load-securing devices as a primary rescue method, this back-up shall have the battery capacity and discharge rate that is sufficient for performing the rescue operation. Maintenance procedures shall ensure that these elements are in proper operating condition at all times.

4.10.2.9 Design of load securing devices shall consider loads on the Flying Performer as per Section 4.5 *Personal Flying Equipment* above, as well as on the performer flying system.

4.10.3 Electrical equipment and control systems

4.10.3.1 General

4.10.3.1.1 Mechanized performer flying systems shall incorporate all aspects of control requirements herein, unless otherwise determined by RA/RR.

4.10.3.1.2 Electrical equipment and control systems shall conform to ANSI E1.6-1-2012, “Entertainment Technology – Powered Hoist Systems.”

4.10.3.1.3 The following sections address additional requirements or exceptions to the referenced standards. In the case of conflicts between the referenced standards and this document, this document shall take precedence.

4.10.3.1.4 The electrical equipment covered by this standard commences at the point of power input into the control cabinet. Suitability of incoming power shall be verified before making the connection.

4.10.3.2 Control functions

4.10.3.2.1 Normal limits shall not be utilized in normal operation of the performer flying system, except when used as part of the homing procedure without the Flying Performer.

4.10.3.2.2 The control system shall have the ability to add local stop switches, interlocks and/or enable switches as required by the Flying System Designer based on RA/RR.

4.10.3.2.3 When a visual monitoring device is used in lieu of direct line-of-sight visual monitoring, a secondary means to stop or disable the system shall be provided. The location and type of the secondary means shall be determined by a qualified person based on RA/RR.

4.10.3.2.4 The delivery of motive force shall be controllable in order to ensure safe flight and safe rescue. Electric motors if used shall have variable speed drives. Hydraulic systems if used shall have proportional valves and pressure relief valves.

4.10.3.2.5 Joystick control shall only provide motion after a hold to enable device is activated. If the joystick is moved from its neutral position prior to activating the enabling device, no movement shall initiate until the joystick is returned to the neutral position.

4.10.3.2.6 The failure or miscommunication of the control system shall not interfere with the proper operation of the safety system.

4.10.3.2.7 The maximum operating speed and acceleration of the system as determined by RA/RR shall be limited by a setting in the variable speed controller. (See Annex note.)

4.10.3.2.8 The control system shall be secured against unauthorized use.

4.10.3.2.9 The control system shall have the ability to limit access to critical settings by use of a password, key operated switch, or other secure means. (See Annex note.)

4.10.3.2.10 When two or more actuators are used to perform an individual flying effect, and the fault of one of the actuators puts the flying performer at risk of harm, the actuators shall be linked by the control system so that any fault shall stop motion of all actuators for that individual effect.

4.10.3.3 Programmable control systems

For all programmable control systems for Performer Flying, the following shall be provided:

4.10.3.3.1 Each direction of travel shall have user assignable software ("soft") limits which shall prevent further motion in the direction of travel. When the soft limit is activated, movement in the opposite direction shall be allowed.

4.10.3.3.2 Soft limits shall be functional in both joystick and run-cue operational modes. (See Annex note.)

4.10.3.3.3 Each axis shall have a closed-loop feedback for position monitoring and control. (See Annex note.)

4.10.3.3.4 The control system shall compare set ("target") values with actual values of speed, position or both, and fault if the difference exceeds the error tolerance as determined by the RA/RR.

4.10.4 Safety functions

4.10.4.1 Limits

Normal and ultimate limits shall be incorporated at both ends of travel. (See Annex note.)

4.10.4.2 Emergency stop

4.10.4.2.1 The category of emergency stop for each axis of motion shall be either Category 1 or Category 0 as determined by the RA/RR, with consideration of effects on the Flying Performer, machinery, and supports.

4.10.4.2.2 The emergency stop system shall include redundancy in the signals from each emergency stop device.

4.10.4.2.3 The emergency stop system shall be designed so that no single fault of an individual component or group of components shall cause the system to fail to an unsafe state.

4.10.4.2.4 The fault condition created by the initiation of an emergency stop shall only be reset by resetting the emergency stop device followed by a separate unique action by the Flying Operator.

4.10.4.2.5 Performer flying systems shall have an emergency stop function that stops the drive system by implementing either a Category 0 or a Category 1 stop. The choice of category shall be on the basis of the RA/RR and the functional needs of the performer flying system.

4.10.4.2.6 Each Flying Operator control station shall be equipped with an emergency stop.

4.10.4.2.7 Activation of any of the emergency stops shall stop all machinery in the performer flying system.

4.10.4.2.8 Variable frequency drives (VFD) with integrated safety functions shall be utilized per the drive component manufacturer's instructions.

4.10.5 Backup operation

4.10.5.1 A secondary means of operating the system other than the primary operator interface shall be provided if failure of the primary operator interface would result in a hazard to the Flying Performer based on RA/RR.

4.10.5.2 The operation of the backup system shall not compromise primary safety functions except as needed to ensure safety of the Flying Performer as determined by RA/RR.

4.11 Facility anchorage

4.11.1 The Flying System Designer shall determine connection points interfacing with the facility structure and shall report associated reaction forces. The determination of appropriate locations and anchorage details for connecting to the facility structure shall be coordinated with the facility's technical representative.

4.11.2 If there is a load rating document for the facility certified by a Professional Engineer, then the Flying System Designer shall evaluate the reaction forces relative to the documented load ratings, if applicable. If the Flying System Designer cannot confirm that the facility structure can safely support the loads based on the load rating document, then the facility's technical representative shall be consulted as per Section 4.11.3 below.

4.11.3 If a load rating document for the facility does not exist or does not pertain to the proposed loading, the facility's technical representative shall evaluate the reported reaction loads on the facility structure and shall make a determination if the facility structure can safely support the performer flying system. The performer flying system shall be implemented only if the facility's technical representative confirms that the facility structure will safely support the loads.

4.12 Engineering related to system installation and erection

The structural adequacy of the Performer flying system during erection and installation shall be evaluated, including limitations imposed by weather.

4.13 Rescue

The design of the performer flying system shall include a written rescue plan with rescue system(s).

4.13.1 Design responsibility

The rescue system shall be designed by a qualified person. The rescue plan shall include references to applicable reference standards employed in the rescue plan, based on the equipment and techniques used. Custom fabricated components shall conform to Section 4.2.9.2 Fabricated Components.

4.13.2 Rescue systems

The rescue systems collectively shall accommodate safe rescue along the entire flight path and shall remain functional during the loss of power. There may be multiple rescue techniques and systems for a flight sequence depending on position, physical condition of the Flying Performer, availability of electromechanical power, etc. The rescue systems shall be developed considering hazards to all persons in the area (the Flying Performer, rescuers, workers, audience members, and others). The rescue systems shall minimize time needed to perform the rescue in order to mitigate the risk to the Flying Performer.

4.13.2.1 Primary rescue

A primary rescue system is required. The primary rescue system shall be the first rescue method utilized unless there are situational restrictions to using the primary rescue system. The primary rescue system shall be designed with the safety of the performer, audience, and rescuers along with expediency as primary design parameters. (See Annex note.)

4.13.2.2 Secondary and subsequent rescue

Secondary and subsequent rescue systems are required. Secondary and any subsequent rescue systems shall be employed when situations arise that do not allow the safe use of the primary rescue system.

4.13.3 Rescue plan design considerations

The rescue plan shall allow a safe rescue to be performed throughout the flight path. (See Annex note.)

4.13.3.1 In order to mitigate the risks of restricted blood circulation and other health problems, the rescue plan shall include provisions to transport the Flying Performer to a safe location and shall minimize the time needed to perform the rescue for all reasonably foreseeable situations that can occur, including system failure, unconscious Flying Performer, and loss of power.

4.13.3.2 The rescue plan shall include protocols for communication during a rescue.

4.13.3.3 The rescue plan shall include readily available contact information for emergency medical personnel, and possibly supplementary rescue personnel such as firemen.

4.13.3.4 If the performer flying system rigging or hoist machinery is used for rescue operations, over-ride devices shall be employed to enable rescuers to operate the equipment separately from the show cueing in a safe condition, which may include controlled descent for machinery operated by computerized controls. If determined by RA/RR, rescue may be performed using non-powered techniques with the machinery. In the case that safety devices are overridden to perform the rescue, operational procedures shall be put in place to mitigate risk.

4.13.4 Special rescue situations

4.13.4.1 Multiple Flying Performer rescue

The rescue plan and staffing of Rescue Riggers and other technical personnel shall include provisions for safely and quickly rescuing Flying Performers in situations where multiple people require simultaneous rescue.

4.13.4.2 Rescue in audience or other public area

Where lowering of Flying Performers must occur in or near the audience, the rescue plan shall include provisions for protecting the audience, clearing a landing zone, protecting the Flying Performer from the audience or evacuating the audience, and for evacuating the Flying Performer to a more protected location.

4.13.5 Rescue equipment

4.13.5.1 Rescue Equipment Components

The rescue system may include elements used for fall protection, assist-rescue and self-rescue systems, rope access systems, building maintenance and inspection access, ladders, movable stairs, personnel lifts, recreational climbing equipment, flying machinery, and/or rigging hardware. All such equipment shall meet applicable, nationally recognized industry standards. (See Annex note.)

4.13.5.2 Fall Protection Equipment

If during a rescue, fall protection equipment is used as a fall protection component, it shall meet the requirements of ANSI Z359.1. If it is used as a rescue component, it shall meet the requirements of ANSI Z359.4.

4.13.5.3 Rescue Rope

Rope used for rescue shall comply with NFPA 1983-2012: Standard on Life Safety Rope and Equipment for Emergency Services. Life safety rope may be General-Use or Light-Use per NFPA 1983 and shall be used with compatible rigging hardware, selected to suit the rescue scenarios that may be encountered in the flying system and the anticipated loads experienced during a rescue.

5 Manufacturing

5.1 Intent

The intent of this section is to establish requirements for the manufacturing of components and subassemblies used in performer flying systems. These components and subassemblies are used by the System Supplier to produce the performer flying system. Variations on the manufacturing requirements shall be permitted pursuant to RA/RR, or review and approval by a Professional Engineer.

5.2 Requirements

5.2.1 The System Supplier shall ensure that all components of the performer flying system are built in accordance with Flying System Designer specifications.

5.2.2 Welding shall be performed in accordance with appropriate AWS standards by AWS certified welders.

5.2.3 Purchased components shall be used and assembled in accordance with component manufacturer’s written specifications, unless a specific deviation is approved in writing by the Flying System Designer and System Supplier.

5.3 Material

Material selection shall be made in accordance with design specifications

5.4 Assembly

Assembly of all components of the performer flying system shall be in accordance with Flying System Designer specifications.

5.4.1 Hardware

5.4.1.1 Torque

Fastener torque requirements and torque values shall be determined by the Flying System Designer. After applying the proper torque, fasteners shall be marked with a painted stripe across the nut or fastener head and bearing surface to indicate that the fastener has been tightened properly, and to indicate slippage or loosening in service, except in locations specifically excluded from striping by the Flying System Designer.

5.4.1.2 Critical connections

Critical Connections as defined by the Flying System Designer shall be marked with a painted “witness mark” to indicate slippage or loosening in service.

5.4.2 Flexible lifting medium terminations

5.4.2.1 Terminations shall be made, inspected, and certified per the instructions provided by the material manufacturer or a Flying System Designer.

5.4.2.2 Terminations shall be made by a person properly trained in the termination method.

5.4.2.3 Qualification for terminating synthetic rope shall require third party or manufacturer's certification of that individual.

5.5 Inspection

All raw materials and purchased parts shall be inspected for defect or damage and verification of material specification upon receipt.

5.6 Factory acceptance testing

5.6.1 The performer flying system shall be inspected to ensure compliance with the Flying System Designer's specifications.

5.6.2 A test weight shall be used for all factory acceptance testing and before the attachment of any person.

5.6.3 All components in the performer flying system shall be load tested at 125% of the WLL.

5.6.4 As applicable, operation of the control system including all limit switches, safety devices and interlock devices shall be confirmed. Mechanical over-speed braking devices may be excluded from this requirement when the brake manufacturer supplies written verification of a successful test of representative samples.

5.6.5 Each hoist in the performer flying system shall undergo a static load test at 125% of the WLL.

5.6.6 Each hoist in the performer flying system shall undergo a dynamic load test at 100% of the WLL and maximum rated speed of the hoist.

5.6.7 Each hoist in the performer flying system shall be tested for performance through the full range of accelerations, velocities, and decelerations.

5.6.8 Each hoist brake shall be tested individually to ensure that the brake will hold at least 125% of the WLL.

5.6.9 The hoist brakes shall be tested in combination to ensure that the maximum applied braking force does not exceed the Flying System Designer's specification and does not exceed maximum allowable accelerations on the Flying Performer as specified herein. (See Annex note.)

5.6.10 The emergency stop function shall be tested at 100% of the WLL and maximum rated speed of the system. This test shall be conducted in both the ascending and descending directions. Components shall be observed for indications of malfunction.

5.6.11 The control systems shall be tested to verify positional accuracy, when applicable.

5.6.12 Each hoist shall be tested for the intended loads as specified by the Flying System Designer.

5.6.13 The final assembly shall be tested for the intended loads as specified by the Flying System Designer.

5.6.14 Any additional tests required by the Flying System Designer shall be conducted.

5.7 Identification

Critical components, as outlined by the Flying System Designer, shall have a serial number or some other unique identifier.

5.8 Documentation

5.8.1 General Requirements

5.8.1.1 The System Supplier is responsible for including component specification sheets into the documentation.

5.8.1.2 The System Supplier shall furnish a system manual or manuals, covering operations and maintenance of the system, or exist electronically such as in PDF format.

5.8.1.3 The system manual shall be composed of an operation section and a maintenance section. The system manual may be bound in multiple volumes.

5.8.1.4 General assembly drawings of the performer flying system shall be included.

5.8.1.5 The system manual shall state the limits of use and include requirements that operation of the performer flying system shall be restricted to competent persons who are trained in the system operation.

5.8.2 Operation documentation

5.8.2.1 The system shall be clearly described in this section and shall include, at minimum:

5.8.2.1.1 A description of each safety function.

5.8.2.1.2 Descriptions of fault indications, including system responses and corrective procedures, when applicable.

5.8.2.1.3 Comprehensive operator instructions.

5.8.2.1.4 Capability of system specific components that may be used during rescue operations.

5.8.3 Maintenance documentation

The maintenance section shall include the requirements for inspection, testing, and maintenance.

5.8.4 Testing documentation

5.8.4.1 Factory Acceptance Testing (FAT)

Each component tested during FAT shall have its testing criteria recorded and saved with that components serial number or other identifying label.

5.8.4.2 Destructive

All destructive testing documents shall be kept on file and made available to local AHJ's if requested.

5.8.5 Certifications

Purchased load-bearing hardware and components supplied by component manufacturers shall bear a visible load rating mark or shall be supplied with a certification of their load rating or strength.

5.9 Installation training

The System Supplier shall provide training to the System Installer, as requested by the System Installer.

5.10 Reused components

5.10.1 Prior to being furnished as part of a performer flying system any used components shall be inspected by a competent person and approved for the intended use by a qualified person.

5.10.2 When used components are used as part of a new performer flying system, the system shall be tested using FAT guidelines as per 5.6 Factory Acceptance Testing.

5.10.3 When used components are intended to replace worn or damaged parts of an existing performer flying system, the replacement components shall comply with Section 5.10.1.

6 Installation

6.1 Intent

This section is intended to ensure that the equipment used in performer flying is properly installed and commissioned in order to ensure the safety of Flying Performers and others potentially affected. Variations on the installation requirements shall be permitted pursuant to RA/RR, or review and approval by a Professional Engineer.

6.1.1 The User shall be responsible to comply with Authority Having Jurisdiction requirements.

6.1.2 It is not the intent of this standard to supersede local, state, or federal regulations.

6.1.3 The performer flying system shall be installed by or under the direct supervision of a qualified person.

6.1.4 The assembly shall be supported and braced to provide stability during erection to prevent buckling, overloading or failure of components.

6.2 Control system commissioning

The System Installer / Flight Sequence Programmer shall set control system operational parameters during installation.

6.3 Documentation

6.3.1 All equipment used in a performer flying system shall have documentation demonstrating proper completion of installation and commissioning. The System Supplier and Flying Safety Supervisor shall

maintain and store documentation from the date of system commissioning acceptance to the date of decommissioning (load-out) of the system which shall include:

6.3.2 Name of installation supervisor and in-service date of system

6.3.3 Commissioning inspection procedures, dates and results

6.3.4 Commissioning testing procedures, dates, results, and name of qualified tester(s).

6.3.5 Documentation package as specified in 5.8 Documentation

6.4 Commissioning inspections

Upon completion of the system installation, the performer flying system shall be inspected as part of commissioning to ensure the integrity of the system. Commissioning inspection procedures shall be determined by the Flying System Designer and System Supplier. (See Annex note.)

6.4.1 The installing qualified person shall ensure that the harness is being used within its intended limits of usage.

6.5 Commissioning testing

The performer flying system shall be tested as part of commissioning to confirm proper behavior when the installation is complete.

6.5.1 Commissioning testing procedures shall be determined by the Flying System Designer and System Supplier. In situations in which a performer flying system is touring, modified testing protocols may be performed on subsequent uses after commissioning first use, as determined by a qualified person based on RA/RR.

6.5.2 Testing shall be performed by a qualified person.

6.5.3 Testing shall confirm compliance with system specifications.

6.5.3.1 Load tests shall be conducted with test weights or other mechanical means of applying force in a manner that does not put any personnel at risk.

6.5.3.2 The forces applied shall be at least equivalent to the characteristic load.

6.5.3.3 Tests shall include anticipated operational conditions over the entire flight path and shall test failure scenarios, including loss of electrical power if applicable. Multiple tests may be required to provide adequate data results.

6.5.3.4 For systems that include powered machinery, each of the following tests shall be performed:

6.5.3.4.1 Load securing device proof load test: 1.25 X WLL with each load-securing device acting alone.

6.5.3.4.2 Static proof load test: 1.5 X WLL with both load-securing devices acting together.

6.5.3.4.3 Dynamic proof load test: WLL with Category 1 stop if applicable, full speed in both directions.

6.5.3.4.4 Power loss proof load test: WLL with Category 0 stop, full speed in both directions.

6.5.4 Tests of normal and ultimate limits shall be conducted using both WLL and minimum anticipated load at full speed in both directions, except as follows:

6.5.4.1 In situations where a lower speed will produce confidence in safe operation of the limits as determined by a qualified person based on RA/RR.

6.5.4.2 In situations where the Flying Performer is descending to the stage or similar landing surface, limits shall be tested to ensure protection of the equipment. Test at WLL is not required.

6.6 Site acceptance testing (SAT)

Such testing commences only after commissioning is completed. SAT may include some or all of the load testing described in Section 6.5 Commissioning Testing.

7 Operational use

7.1 Intent

This section is intended to ensure that the equipment used in performer flying is properly used in order to ensure the safety of Flying Performers and others potentially affected. Variations on the operational use shall be permitted pursuant to RA/RR.

7.2 User's documentation package

The System Supplier shall supply a User's documentation package to the User in a timely fashion prior to system commissioning, which shall include the following:

7.2.1 Description of the flying system.

7.2.2 Definitive statements about the operating limits of the system.

7.2.3 Indicate where the Performer Flying System ends and how it interfaces with the support structure, including loads imparted to the support structure.

7.2.4 Maintenance, inspection and testing requirements for in-service use.

7.3 Operational documentation

A performer flying system shall have documentation describing the use and care of its equipment from the date of system commissioning acceptance to the date of decommissioning (load-out) of the system.

7.3.1 The Flying Safety Supervisor shall maintain and store documentation, and shall provide copies to the User when major changes occur and at regular intervals.

7.3.2 For each activity, the name of the person performing the activity, date and results shall be recorded in the documentation.

7.3.3 Documentation shall include:

7.3.3.1 Maintenance procedures, dates performed, and results.

7.3.3.2 Daily inspection procedures performed by a competent person.

7.3.3.3 Periodic inspection procedures performed by a competent person.

7.3.3.4 Daily testing procedures performed by a qualified person.

7.3.3.5 Periodic testing procedures performed by a qualified person.

7.3.3.6 Responsibilities of each person involved in the performer flying, including dates of such service.

7.3.3.7 Records of personnel training, including types of training, dates, and instructor name(s).

7.3.3.8 Removal from service date(s), reasons for removal, and by whom.

7.4 Rental documentation

7.4.1 When equipment is rented, the equipment owner shall keep documentation for the entire duration of the rental.

7.4.2 Documentation shall include:

7.4.2.1 Identification of the User and/or person or entity who rented the equipment

7.4.2.2 Dates of the rental

7.4.2.3 Inspections and tests performed prior to rental

7.4.2.4 Any incidents reported during the rental period

7.4.2.5 Notifications from renter of damage or incidents involving equipment

7.4.3 Operational documentation (as per Section 7.3 Operational Documentation above) for a particular User shall be furnished to the equipment owner if requested.

7.5 Maintenance

Routine maintenance service shall be performed to ensure that all of the equipment is in proper working order.

7.5.1 Such maintenance procedures and intervals shall be determined by the System Supplier based on a RA/RR.

7.5.2 The Flying Safety Supervisor shall assign maintenance assignments to the technicians, and the Flying Supervisor shall supervise the work.

7.6 In-service inspections

Periodic and daily inspections shall be performed to ensure the continued integrity of the system.

7.6.1 Such inspections shall be determined by the Flying System Designer, System Supplier, Fly Safety Supervisor, and User based on a RA/RR.

7.6.2 The performer flying system is to be visually inspected daily, preferably before each use, regardless of whether it is being used for rehearsals or performances. The Flying Safety Supervisor shall designate an inspector, and shall supervise such inspections. Any observation of note and any adjustments made shall be documented and submitted to the Flying Safety Supervisor.

7.6.3 The flying equipment shall not be operated if concerns arise as a result of inspections regarding the safe use of the system. The performer flying system may be used only after the concerns are resolved and a test has been conducted yielding positive results.

7.6.4 The rescue equipment shall be visually inspected periodically, in accordance with ANSI Z359.1 and Z359.4 respectively, regardless of whether it is being used for rehearsals or performances. The Flying Safety Supervisor shall designate an inspector, and shall supervise such inspections.

7.7 In-service testing

Periodic testing shall be performed to validate the continued safety of the system. (See Annex note.)

7.7.1 Such testing procedures shall be determined by the Flying System Designer, System Supplier and User based on a RA/RR.

7.7.2 The performer flying system is to be load tested at predetermined intervals, using the anticipated amount of load to be flown, regardless of whether it is being used for rehearsals or performances. Testing intervals shall be determined by the Flying System Designer, System Supplier and User based on a RA/RR. The Flying Safety Supervisor shall designate or hire a tester, and shall supervise such testing.

7.7.3 The flying equipment shall not be used if deficiencies or concerns regarding the safe use of the system arise as a result of the testing. The performer flying system may be used only after the concerns or deficiencies are corrected and a test has been conducted resulting in positive results.

7.8 Training

All people directly or indirectly involved in the performer flying effects shall be appropriately informed and trained regarding the dangers, hazards, safety measures, operational requirements and procedures, rescue procedures, and responsibilities of the various participants involved in the use of the performer flying system. Training shall include safe access to and egress from all locations where a flying performer connects to the flying system. Personnel directly involved in the use of the performer flying system shall be adequately trained so as to be competent in its proper and safe use. All training shall be repeated at regular intervals to be determined by the Flying Safety Supervisor.

7.9 Operation

7.9.1 General

7.9.1.1 No member of the flying team shall participate in a flying effect if his or her ability to do their assigned job is impaired. For example: by alcohol, drugs, fatigue, or physical or mental disability.

7.9.1.2 Once the flying choreography is established, it shall only be changed by the Creative Designer in consultation with the Flying Safety Supervisor. Choreography shall not be changed by the stage director, the choreographer, the performers, or any other individual who is not qualified or authorized to make these changes.

7.9.1.3 Only a qualified person shall be allowed to modify control system operational parameters without the direct supervision of the System Installer and the approval of the Flying System Designer.

7.9.2 Flying Operator

7.9.2.1 Flying Operators shall have an unobstructed view of the Flying Performer's flight path while flying a performer. When a Flying Operator's direct line of sight is obstructed or compromised, the use of cameras and monitors, trained Spotters, or infrared devices is acceptable.

7.9.2.2 The User shall provide the Flying Operators a clear, stable, non-distracting area in which to operate.

7.9.2.3 All personnel necessary for the safe operation of a flying sequence, as specified by the Flying Safety Supervisor, shall be present for all rehearsals and performances when the system is to be used.

7.9.3 Flying Supervisor

The Flying Supervisor shall be in attendance at all times when a person is flown by the performer flying system, and shall confirm prior to each use that each Flying Performer is in a healthy mental and physical condition to perform flying.

7.9.4 Rescue team

A complete rescue team, including the Incident Commander, Rescue Rigger(s) and First Aid Attendant, shall be in attendance whenever a person is flown.

7.9.5 Harnesses

7.9.5.1 Each harness shall have a label designating the Flying Performer to which the harness is assigned.

7.9.5.2 Performer flying harnesses shall only be used as specified on the harness label or harness manual.

7.9.5.3 The initial harness fitting on the Flying Performer shall be done by a qualified person. Harnesses shall be adjusted to each Flying Performer and should not cause undue discomfort when used in normal operation.

7.9.5.4 A competent person shall inspect each harness prior to each use.

7.9.5.5 A competent person shall check the fit of the harness prior to each use.

7.9.6 Communication

7.9.6.1 A predetermined chain of communication shall be established amongst all members of the flying team.

7.9.6.2 The Flying Performer shall be trained in communicating nonverbally with the Spotter.

7.9.6.3 Communication methods shall be secure and reliable.

7.9.7 Stops

7.9.7.1 If the Spotter, Observer, Flying Operator or Flying Performer identifies a problem that could affect the safety of the Flying Performer, he/she shall initiate a stop either directly or by informing the Flying Operator who will initiate a stop. An unplanned stop can also occur due to a fault in the performer flying system.

7.9.7.2 If a stop occurs, the Flying Operator shall inform the Flying Supervisor who will determine what action is to be taken. The Flying Supervisor shall inform the Stage Manager of the action to be taken, and shall inform the Incident Commander if a rescue is required.

7.10 Rescue

7.10.1 Rescue preparation

7.10.1.1 The appropriate and competent personnel shall be trained in rescue operations.

7.10.1.2 The rescue operations shall be rehearsed by personnel involved. Alternate scenarios may need to be rehearsed depending upon the system and the RA/RR

7.10.1.3 Rescue personnel shall be assigned specific duties for rescue scenarios.

7.10.2 Rescue operations

7.10.2.1 The rescue operations shall follow the rescue plan developed per Section 4.13 Rescue, which shall be established prior to flying people with the performer flying system.

7.10.2.2 The Incident Commander shall take overall command of the area and the rescue operation when a rescue is initiated.

7.10.3 Post rescue treatment of Flying Performers

Immediately after a Flying Performer is rescued and brought to a safe location, the First Aid Attendant shall examine the Flying Performer for possible injury or shock. Medical personnel shall be contacted if required. (See Annex note.)

7.11 Inspection and testing after an incident

7.11.1 When any equipment in the system has sustained forces that exceed normal operational conditions, or has been exposed to potentially harmful environmental situations (weather events, prolonged periods of inactivity, adverse storage conditions, or exposure to potentially harmful substances), such equipment shall be removed from service and fully evaluated by a qualified person.

7.11.2 The qualified person shall inspect for any damage or excessive wear, and shall recommend testing, if necessary.

7.11.3 The evaluation shall be documented noting the condition, inspections conducted, tests conducted, and resulting course of action taken.

7.12 Post-use

Upon completion of the system disassembly, all reusable components shall be thoroughly inspected, serviced (cleaned or otherwise maintained as per maintenance manual), documented, and stored in accordance with the System Supplier's recommendations. Non-reusable components shall be discarded and or destroyed as per the System Supplier's recommendations.

8 Storage

8.1 Intent

The intent of this section is to ensure that any equipment that is to be reused in performer flying systems is stored in a manner that retains the integrity of the equipment.

8.2 Documentation

Items that are to be reused and placed in storage or transported between applications shall be inspected for defects and documented by a competent person before being reused.

8.3 Environmental conditions

Items shall be stored in an environment as per the System Supplier's recommendations. All items shall be kept free from harmful exposure to high humidity and damp conditions, corrosive contaminates, ultraviolet radiation, abrasive wear, high temperatures for fiber materials, and high or low temperature extremes for plastic parts.

9 Repair and removal from service

9.1 Intent

This section is to ensure that any equipment unfit for service by damage, defect, or end of service life is repaired or disposed of in an appropriate manner.

9.2 Documentation

9.2.1 When a piece of equipment has been removed from service, a report shall be created that documents the date of inspection, inspection results, date of removal, reasons for removal, date of disposal or repair, and method of disposal or repair.

9.2.2 If a qualified person determines that a piece of equipment is permitted to be returned to service, documentation of this assessment shall be created.

9.2.3 Records shall be kept by the Flying Safety Supervisor for the run of the show or by the equipment owner, as applicable.

9.2.4 When rental equipment is returned to its owner, the Flying Safety Supervisor shall provide copies of these records to the equipment owner.

9.3 Damage

If any component fails the inspection or testing criteria, or is suspected of being defective, the component shall be removed from service and marked accordingly. Any component damaged beyond repair shall be permanently removed from use or service.

9.4 End of service life

Any equipment that has exceeded its lifespan as defined by the component manufacturer, Flying System Designer, or Professional Engineer shall be permanently removed from service.

9.5 Disposal

Any equipment that is to be permanently removed from service shall be appropriately disposed of in a manner that ensures it cannot be returned to service. This may require physical destruction of the item before being discarded.

9.6 Repair

9.6.1 Repair assessment

A qualified person shall determine whether the equipment removed from service is capable of being repaired.

9.6.2 Return to service

Returning an assessed component back into service shall be permitted, if the assessment results show that the component does not lessen the strength and durability of the performer flying system.

9.6.3 Repairing a component

Repairing a component shall be permitted if the repaired component does not lessen the strength and durability of the performer flying system.

9.6.4 Repair procedures

Repairs shall be conducted according to the System Supplier’s specifications or using details developed by a qualified person.

Annex A, Commentary

This commentary is not part of the Standard and contains no mandatory requirements. It offers some explanatory information about the clauses in the standard. The relevant clauses have the same clause number, but without the "A" prefix. The clause numbering here is not continuous because no comments are offered on some of the clauses in the Standard.

Since no mandatory requirements are stated in this commentary, if there is any disagreement between the text of this annex and the requirements stated in the body of the standard, the requirements in the body of the standard shall prevail.

A2.2 AHJ

An AHJ is typically the governmental agency or sub-agency which regulates the work, such as a building department, fire marshal, department of labor, health department, OSHA, etc. In most cases, the AHJ is defined by the municipality in which the performer flying installation is located.

A2.4 axis

In automated systems axes are typically assigned effect numbers and names. Sometimes axes are called “effect” or “effect number” when referencing an axis of motion.

A2.9 characteristic load

The characteristic load is derived from the total self-weight (dead load) of who and what is being flown, i.e., the performer, harness, ride-on prop if used, performer spreader bar if used, and lifting medium. The forces from self-weight are magnified by the anticipated dynamics of motion, often expressed in terms of G’s (acceleration) in whatever directions are involved in the flying routine, in order to determine the characteristic load.

A2.12 design factor

Possible design codes include AISC 360-10 "Specifications for Structural Steel Buildings” and ADM1-10 “Aluminum Design Manual - Specifications for Aluminum Structures.” The LRFD live load factor is typically 1.6.

The design factors for performer flying herein are typically 20% greater than their counterparts in ANSI E1.6-1-2012. The design factor for WLL provides a conservative safety margin for uncertainty in determining dynamic forces. In situations where there is substantial confidence in determining the characteristic load, the Flying System Designer is allowed to use a reduced design factor for WLL; this

reduction may be beneficial in keeping components from being excessively large in situations where the dynamics are relatively low.

A2.13 design factor against yield

Equations involving material yield typically pertain to member sections, and not to fasteners, hardware, and flexible medium. All of Annex Section A2.12 also pertains to this Annex section.

A2.16 fleet angle

In all sheave instances and in most drum instances, defining fleet angle as a measurement against a line drawn perpendicular to the rotational axis is valid and accurate as shown in Figure A1 below. In these instances the allowable angle at the drum and the sheave are the same. In some instances, typically with smaller diameter drums used in zero fleet applications, it is more accurate to measure fleet off of a line running axially down the center of the groove, or to put it differently a line that follows the helix angle of the groove as shown in Figure A2 below. In these instances the angle as measured at the drum and the angle as measured at the sheave may be different depending on the mounting arrangement of the sheave. In these instances it cannot be assumed that the two degree compliance at drum will equal compliance at the sheave or vice versa.

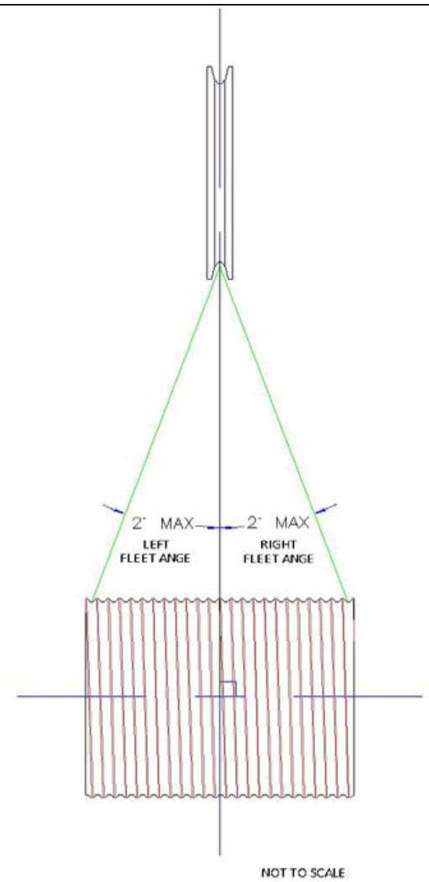


Figure A1

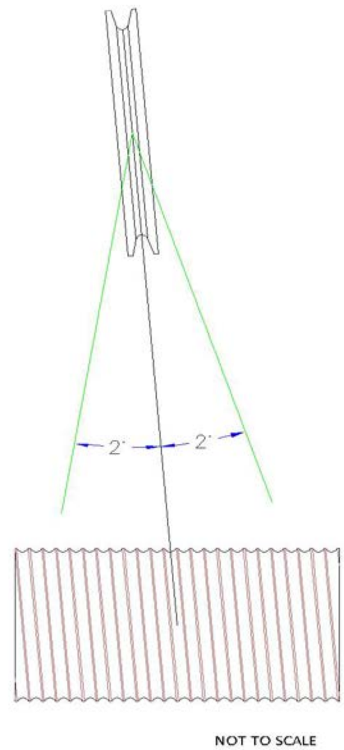


Figure A2

A2.17 full speed

For manual flying systems, full speed includes speeds achieved by mechanical advantage and increases in maximum acceleration and velocity achieved via change in operator position (jumping off of a ladder). For automated systems, full speed is typically the maximum speed of the hoist or winch as determined by the flying system designer.

A2.19 lifting medium

When Lifting Medium is a wire rope, it sometimes called a fly wire.

A2.48 ultimate load carrying capacity

The ultimate load carrying capacity is the load at which the component fails. For example, for a steel member that will fail by fracturing rather than by becoming unstable, the ultimate load carrying capacity is

directly related to the ultimate tensile stress, not the yield stress. The ultimate tensile stress is higher than the yield stress.

A3.1 Intent

Performer flying is safest when the various roles and associated responsibilities are clearly understood by all persons involved.

A3.9 Flying Supervisor

The Flying Supervisor is sometimes called a Flying Director.

A4.2.4.1 When physical testing is used to determine the strength of a component or assembly, this section states that such testing shall be performed in accordance with a recognized national standard. Examples include, but are not limited to the following:

- International Building Code, latest edition, Section 1714
- The Aluminum Association "Specifications & Guidelines for Aluminum Structures" – Section 9 Testing
- ASTM E73 "Standard Practice for Static Load Testing of Truss Assemblies"

A4.2.4.2 Design factors are included in the following sections:

- Section 4.3.5.2 Tensioned cable tracks
- Section 4.5.1.6 harnesses
- Section 4.5.2.5 ride-on props
- Section 4.6.5 quick-connect hardware
- Section 4.7.3 load-bearing hardware
- Section 4.8.4.1 flexible lifting medium
- Section 4.8.4.2 In-view flexible lifting medium
- Section 4.8.4.3 rigid lifting medium
- Section 4.9.1 static load bearing components

A4.2.6.3 Elements with single point failure conditions are common in performer flying, such as winch lines and carabineers. Suitable safety factors are used to mitigate these single point failure risks.

A4.2.7.2 Sacrificial damage to readily replaceable end stop elements not relied upon for structural support is acceptable. The system should not be used until damaged elements are replaced.

A4.2.8.4 Proper sizing of grooves in sheaves and drums should typically follow manufacturer's recommendations and machining standards. Deviations may be permissible if determined by the Flying System Designer using RA/RR, with consideration of rope material and type, cycles, anticipated wear, maximum loads, and maximum operating speed and accelerations.

A4.2.9.1.6 Open end terminations include hooks without spring latches. As per Section 4.6 Quick-Connect Hardware, any device that opens on a regular basis shall have a redundant means of actuating that open movement. Use of hooks with spring latches or “gates” (for example on chain motors) should be evaluated as part of the RA/RR process and special attention should be paid to potential for slack conditions that may negate any protection the spring latch provides.

A4.3.2.1 RA/RR is often best performed by involved persons engaging in a discussion of the issues. While a qualified person should be fully capable of performing RA/RR alone, a discussion by two or more competent people can produce satisfactory results. For example, a competent person on site can consult via telephone and email with a supervisor (competent or qualified) to address RA/RR.

A4.3.3.1.3 Performer peak load refers to the pressure that the Flying Performer will experience through the body at the time of peak load in the performer flying system. Performer peak load may be higher than peak load on a performer flying system or component of a performer flying system, particularly in instances of multi-axis 3D or Flying V effects.

G-Forces are influenced by:

- Load of Flying Performer, Ride-on prop, and lifting medium
- Speed
- Negative and positive acceleration
- Brake onset time
- Power transmission system inertias
- Stiffness of equipment support frame and static load bearing components
- Stiffness of support structure

Maximum allowable G-Forces are determined by evaluating all of the following conditions:

- Physical fitness of the person experiencing the force
- Position of the body
- Duration of exposure to the forces

This section states that the Flying System Designer and the flying harness designer shall take into account how performer peak forces are being distributed through the Flying Performer’s body. These considerations should be made not only for characteristic loads but for peak loads generated during emergency stops, reasonably foreseeable misuse, and equipment or power failure situations. Flying effects and the harnesses created for flying effects differ from fall arrest harnesses. To state the obvious, the intent of flying effects is to support a Flying Performer in a manner that is consistently countering the effects of gravity. In fall arrest scenarios the period of “free fall” leading to sudden stopping can generate very large forces.

For effects requiring high speeds and for instances where Flying Performers are tethered to a performer flying system but not yet supported by the performer flying system, the flying harness could potentially see forces that are similar to fall arrest harnesses. For example, if an emergency stop occurs when traveling up on a flexible lifting medium, the Flying Performer will continue up, stop and then free-fall, engaging the lifting medium at the same speed at which the emergency stop occurred, resulting in a shock-type load. The Flying System Designer and harness designer should consider all potential modes of use, emergency stops, reasonably foreseeable misuse, and equipment or power failure situations, and consider the forces due to rapid acceleration or deceleration.

Flying harness designers should determine not only the overall effects of G-forces, but the effects of localized impact force and pressure on the Flying Performer's body at the point of contact of the harness. These forces should be evaluated for both the positive and negative acceleration forces.

In writing this document various research papers on the effects of G-Forces and impact on the human body were reviewed. These documents include but are not limited to ASTM F2291 "Standard Practice for Design of Amusement Rides and Devices," NASA Memorandum "Human Tolerance to Rapidly Applied Accelerations" by A. Martin Eiband, June 1959; the Wayne State Tolerance Curve studies; research done by Colonel JP Stapp in the 1950's; and a comprehensive report prepared by Harry Crawford for the Health and Safety Executive of East Kilbride, Glasgow, UK in 2003. Research into the effects of G force and body impact forces spans disciplines as varied as amusement rides, space flight, performance racing, military maneuvers, firefighting, boxing and other sports, as well as fall arrest. To sum up a vast and varied set of data, the human body can tolerate very large amounts of G-Forces for very short periods of time assuming the person being subjected to the force is physically fit & properly trained. (See Figure A3 below.)

When evaluating G-forces, performer flying system designers and harness designers should also consider the position of the body in relation to the direction of force with an evaluation of potential negative as well as positive G's. (See Figure A4 below.) Typically negative G's occur when moving downward, where the blood is forced toward the brain. However an upside-down oriented Flying Performer being flown in the up direction could experience similar effects. High G's can be maintained in the horizontal direction but again, body position and whether you're forcing blood towards or away from the brain is of most concern.

Flying System Designers via a rigorous RA/RR process may establish allowable loads that vary from the values presented in this document. For instance, it is quite possible that a professional stunt person could withstand larger forces than a performer of flying effects in a small amateur production. Rigorous attention to maximum forces should be paid and measures should be taken to minimize performer peak load.

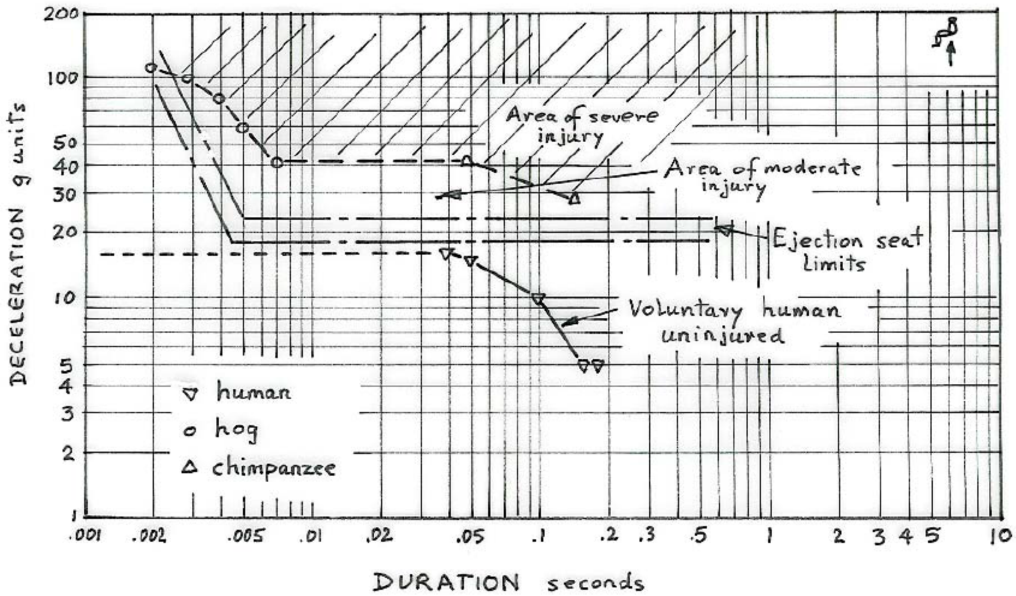
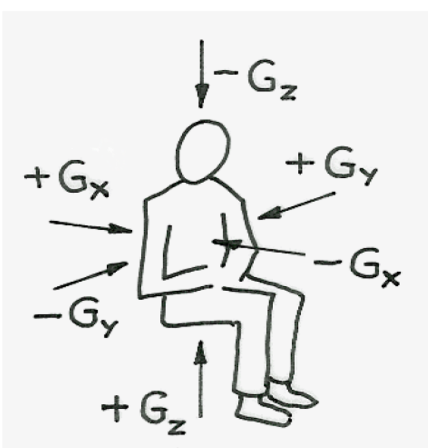


Figure A3. Survivable abrupt positive G ($+G_z$) impact, from Eiband



Upward accel. (positive G)	$+G_z$	Eyeballs down
Downward (negative G)	$-G_z$	Eyeballs up
Backward accel.	$-G_x$	Eyeballs out
Forward accel.	$+G_x$	Eyeballs in
Acceleration to right	$+G_y$	Eyeballs left
Acceleration to left	$-G_y$	Eyeballs right

Figure A4. Direction of G-force relative to body position

A4.3.3.1.6 This section states that in addition to the effects of G-forces, the flying system designer and harness designer shall consider the effects of pressure exerted on the human body due to point of contact with the harness. The intent being to limit, as much as is practicable, the performer’s exposure to bruising, abrasion or general discomfort.

Current force values for body harnesses in other industries have been derived from studies of G-forces and the effects of rapid accelerations (both positive and negative) on the human body. Most of these studies were conducted nearly half a century ago and there is surprisingly little modern data available. Most modern studies, white papers and standards reference the Stapp studies conducted in the 1950's.

In an effort to determine a threshold of tolerance for the human body due to pressure exerted by forces transmitted through the harness, the task group referenced a variety of scientific studies and white papers listed below. Most notably this except from a 1967 seat belt study that states:

> "Note that belt forces of 1518-3588 pounds (31.0-74.7 psi belt pressure at .001-.003 seconds duration at 15-23 G on abdomen were found in the Lewis and Stapp tests of volunteers. Only three of these subjects were reported (out of 19) to have received belt bruises in the impingement area, but two others were sore at the lower margin of the rib cage, one for four days, one for two weeks. However, these forces would probably be close to the subjective tolerance limits, since these subjects were all healthy young males. It is important to note that a difference was found in subjective tolerance not only between individuals, but within the same individual on different runs. In similar tests a subjective limit of 9 G was found to be the highest voluntary level in the lateral position (97)."

In an attempt of put a maximum value on the pressure exerted by a harness, we looked at both allowable forces in fall arrest harnesses divided across an estimated surface area and compared it with the threshold values stated above. The result being a maximum suggested value of 75 PSI as derived from the force per area calculations and not exceeding the high end of the tolerance scale from the above referenced seatbelt study. This value is offered here as a high limit reference only. The language of this documents does not disallow the manufacturer of flying harnesses from establishing higher or lower thresholds provided proper evaluations and testing is completed that supports the design intent.

Suggested Reading:

"Seat Belt Injuries in Impact" by R. G. Snyder, Ph.D., and J. W. Young, A. M. of *Ford Motor Company,* C. C. Snow, Ph.D. of *Federal Aviation Agency, and* P. Hanson, M. S. of *6571st Aeromedical Research Laboratory, USA F. Reprinted from* THE PREVENTION OF HIGHWAY INJURY *from The Proceedings of a Symposium held in honor of The University of Michigan's Sesquicentennial Celebration and sponsored by the University's' Medical School and Highway Safety Research Institute.* April 19-21, 1967. *Published by* HIGHWAY SAFETY RESEARCH INSTITUTE, The University of Michigan, 1*967.*

"Survivable Impact Forces on Human Body Constrained by Full Body Harness" HSL/2003/09, Prepared by Harry Crawford for the Health and Safety Executive (http://www.hse.gov.uk/)

"Human Tolerance and Crash Survivability" by Dennis F. Shanahan, M.D., M.P.H., Injury Analysis, LLC, 2839 Via Conquistador, Carlsbad, CA. *Paper presented at the NATO Research and Technology Organization Human Factors and Medicine Panel (RTO HFM) Lecture Series on*

“Pathological Aspects and Associated Biodynamics in Aircraft Accident Investigation,” held in Madrid, Spain, 28-29 October 2004; Königsbrück, Germany, 2-3 November 2004, and published in RTO-EN-HFM-113.

A.4.3.3.1.8 Anticipated peak loads usually include the following: emergency stops, uncontrolled stops, control system faults, equipment failure, free-fall shock loads, unplanned rapid acceleration, and other unplanned shock loading conditions.

A4.3.3.2.2 Maximum tension in tensioned cable tracks is determined using the catenary geometry, cable track pretension, weight of cable tracks, weight of supported performer flying system elements, and the dynamic forces. The selected design factor for supported performer flying system elements in tensioned cable track systems should account for the ability to accurately calculate forces resulting from the often sensitive variables involved in the geometry and forces in a catenary system, hazards caused by a falling tension line, as well as the difficulty often involved in inspecting these systems.

A4.5.1.2 The harness and lifting medium supports the Flying Performer’s body weight throughout the flying routine from single or multiple pick-up points and not under the conditions normally associated with fall arrest equipment. When a person is supported by a performer flying system, fall arrest equipment is not needed and could present a safety hazard.

A4.5.1.3 Flying Performers should not be suspended in the harness for long periods of time in order to avoid risks to health associated with suspension trauma.

Suspension trauma (Syn. "orthostatic shock while suspended"), also known as harness hang syndrome (HHS), or orthostatic intolerance, is an effect which occurs when the human body is held upright without any movement for a period of time. If the person is strapped into a harness or tied to an upright object they will eventually suffer the central ischemic response (commonly known as fainting). If one faints but remains vertical, one risks death due to one's brain not receiving the oxygen it requires.

People at risk of suspension trauma include people using industrial harnesses (fall arrest systems, abseiling systems, confined space systems), people using harnesses for sporting purposes (caving, climbing, parachuting, etc.), stunt performers, aerial performers, etc.

During rehearsals, the Spotters and Flying Supervisor should keep constant watch and communicate to the Flying Performers as needed to assure comfort and safety when suspended from harnesses.

If a flight during rehearsals or production is subject to stops and starts with the Flying Performer in the harness, it is advisable to have a suitable method to alleviate pressure in harness, such as ladders, boson's chair, stirrups, Tee bar, or other temporary support element.

A4.5.1.4 Warnings and/or user manual specifications should be used to clarify important requirements, e.g., that both sides of a hip harness must be used or built-in shock absorption mechanisms are included.

Harnesses designed and constructed for a specific individual performing a specialized stunt should clearly denote the use.

A4.5.2.5 Strength Design Factors

Aesthetics and/or ergonomics of ride-on props are often important factors in design, which may compete with satisfying strength design factors of members. A qualified person could determine that reduced design factors are acceptable for elements of ride-on props based on the RA/RR process, using other factors to compensate for the reduced design factors, such as enhanced maintenance and inspection procedures. For example, hand and foot holds should consider the risks associated with non-optimal shapes and sizes versus using reduced design factors.

A4.8.2.2 Swivels

It is advisable to use a rotation-resistant rope that will rotate minimally when loaded, in order to mitigate the hazard of the rope causing rotation of flying performer suspended from a flexible lifting medium and to ensure the safety of personnel beneath the flying area. The swivel helps relieve the any induced rotation on the rotation-resistant rope resulting from angular deflections at a sheave or drum.

Other rotation-resistant ropes that have less resistance to rotation when loaded, will likely need a swivel to help minimize the likelihood that the flying performer will rotate. The Flying System Designer should be aware that excessive rope rotation can compromise rope performance and can also cause a reduction in ultimate breaking strength of the rope. This reduction will depend on the characteristic load and the rotational properties of the selected rope.

The selection of the rope and swivel for the intended performer flying routine and loads should be assessed by a qualified person, who should determine the criterion and intervals for examining the rotating rope and swivel hardware.

Suggested Reading:

> "ODN 0791: The Use of Swivels with Steel Wire Ropes," by R. Verrett *of Wire Rope Technology, Germany*, and I.M.L. Ridge of *The University of Reading, United Kingdom. Reprinted from* OIPEEC ROUND TABLE CONFERENCE – Bethlehem, August 2001.

A4.8.4.2 In-View Flexible Lifting Medium

It is often desirable for creative reasons to make the in-view flexible lifting medium "invisible" from the audience perspective to the greatest extent possible. If the in-view flexible medium used for this application are not bent over sheaves or similar elements during use, the effects on the medium are less demanding than when flexed. As a result, lower design factors can produce a safe design for such elements, when combined with regular monitoring and/or frequent replacement of these in-view flexible medium. Such reduced design factors are not suitable for out-of-view elements.

A4.8.6 Fatigue Factors

All lifting medium materials are subject to fatigue over their useful life, and fatigue can affect the actual in-use strength of the material being utilized. The Performer flying system maintenance procedures and schedules are determined partially by prediction of the fatigue life of these materials and the desired frequency of inspection and replacement of the lifting medium.

A4.9 Static load bearing components

These elements include but are not limited to winch frames, equipment support frames, sheave block support frames, carrier support tracks, support brackets, support trusses.

A4.10.2.2 Directly coupled means that there is no intervening belt, chain, clutch, gear or other variable device between the load securing device and lifting medium termination point.

A4.10.3.2.7 Each mechanized actuation device should be equipped with an overload sensor which would disable actuator movement when the load exceeds the value determined by the RA/RR. The intent of this clause is to ensure that parameters related to safe operation of a performer flying hoist are stored in the drive parameters (“hard coded”) and not kept only as a “soft coded” parameters in the GUI or “front end.” A mismatch between drive parameters and software parameters can be confusing to operators and as such means should be taken to match drive settings with soft coded parameters and cue settings.

A4.10.3.2.9 The control system critical settings may include:

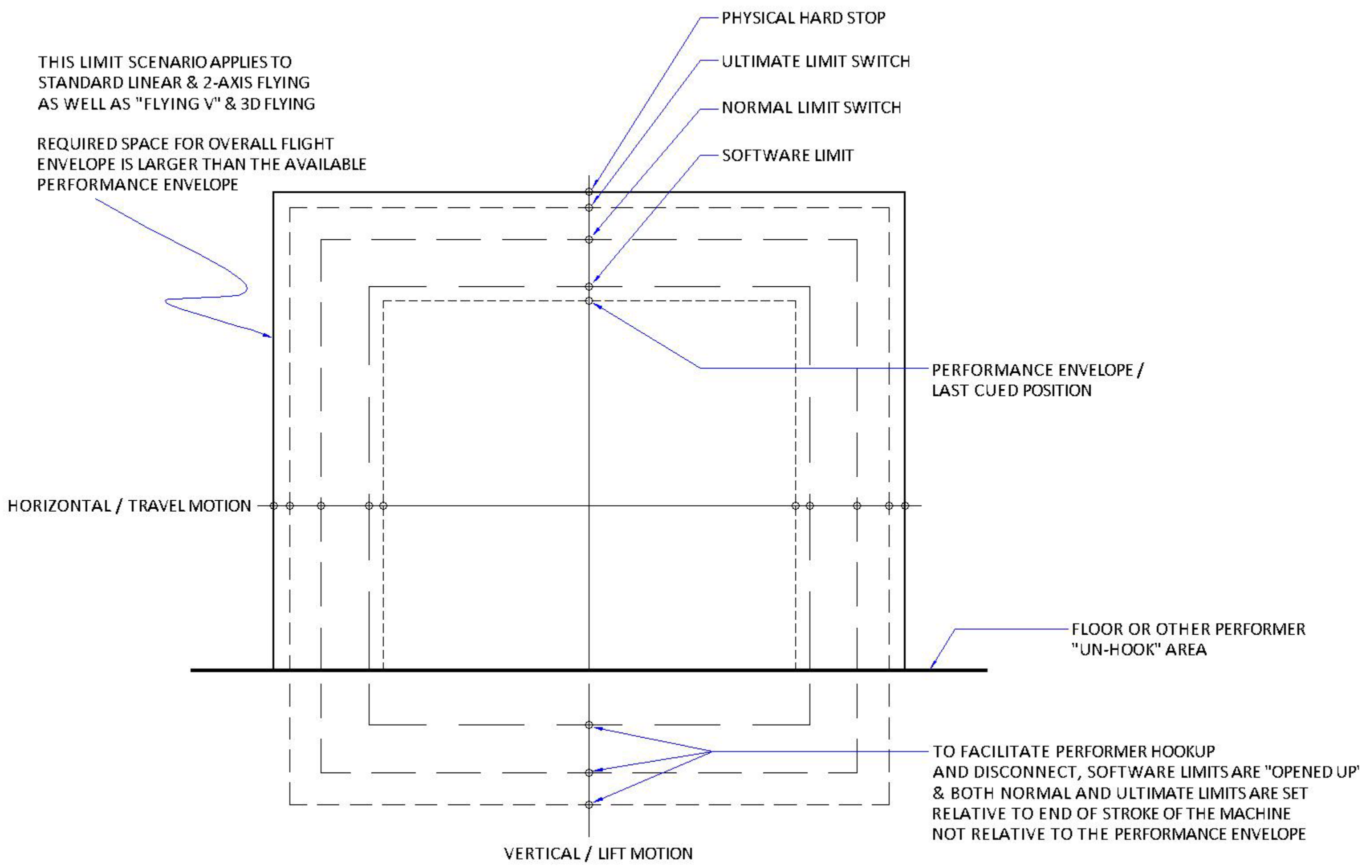
- Soft Limits
- Maximum Speeds
- Acceleration/Deceleration Limits

A4.10.3.3.2 The system may have different programmed soft limit values based on operational mode.

A4.10.3.3.3 Dual position monitoring should be incorporated into each mechanized means of actuation. Use RA/RR to assess safety of Flying Performer. If dual position monitoring is used, the system should compare these position monitoring devices during operation and should stop motion if an unacceptable variance is detected. The category of stop should be determined by the RA/RR.

For simple, single axis performer flying systems, the Flying Operator can close the loop with visual line of sight to the Flying Performer as determined by the Flying System Designer.

A4.10.4.1 Limits



Schematic: Relative limit locations

To facilitate Flying Performer hookup and disconnect, software limits are extended beyond the floor level; Normal and ultimate limits are set relative to the end of stroke of the machine and not relative to the performance envelope.

A4.13.2.1 Primary Rescue

Primary rescue is typically done by performing an emergency landing using the flying system.

A.4.13.3 Rescue Plan Design Considerations

During performance, if an incident occurs requiring the Flying Performer to be removed immediately from flight, the first choice is to continue using primary fly rigging to transport the Flying Performer to the original intended stop position or to an alternative offstage exit position, if feasible for the Flying Performer. While rescuing the Flying Performer is the primary concern, if a stop must be performed mid-

flight in view of the audience, it is advisable to obscure the Flying Performer as much as possible and/or attention drawn elsewhere, or by evacuating the audience. Such procedures should be planned and practiced in advance. Rescue rigging and associated hardware should only be used when it is the only method available to perform a safe rescue. The condition of the Flying Performer is vital in determining the best course of action for quickly removing the Flying Performer from flight and providing care.

A.4.13.5.1 Rescue Equipment Components

There are a number of nationally recognized standards for the potential equipment used for rescue systems. Rope access rescue equipment and techniques are becoming more common. The following is suggested reading for rope access rescue:

> "Safe Practices for Rope Access Work," published by Society of Professional Rope Access Technicians (SPRAT), USA, 2012. (http://www.sprat.org/resources/Safe_Practices%20-%20August%202012.pdf)
>
> "Certification Requirements For Rope Access Work, Version 13," published by Society of Professional Rope Access Technicians (SPRAT), USA, 2013. (http://www.sprat.org/resources/SPRAT_Certification_Requirements_WebVersion.pdf)
>
> "Technical Rescuer: Rope Levels I and II" by Jeff Mathews, Published by Delmar - Cengage Learning, USA, 2009.
>
> "CMC Rescue Rope Manual, Revised 4th Edition," Edited by James A. Frank, published by CMC Rescue, Inc.
>
> "Rope Rescue for Firefighting" by Ken Brennan, Published by PennWell Publishing, USA, 1998.
>
> "The Essential Technical Rescue Field Operations Guide, Edition 4," by Tom Pendley, Published by Desert Rescue Research, USA, 2010."

A.5.6.9 Maximum braking torque will have an effect on emergency stop and peak stop G-forces as indicated in Annex note A.4.3.3.1.3. This force should be considered when examining characteristic (dynamic), and emergency stop and other peak load stop loads that can be transmitted to the Flying Performer, Performer flying system equipment, and supporting structures. Excessive braking or too rapid deceleration can exert forces upon the Flying Performer that could cause injury or death.

A6.4 Commissioning Inspections

Inspections may also include structural inspections, such as weld, high strength fastener, and post-installed anchor inspections performed by a Certified Inspection Agency in accordance with the applicable building code.

A7.7 In-service Testing

Flying equipment should be tested according to frequency and type of application, so that defects and damage are detected in a timely fashion. The inspection intervals should be determined as part of the

risk assessment, considering the component fabricators' guidelines and the intended frequency of use of the equipment.

Testing may also include structural tests, such as non-destructive weld testing, performed in accordance with the applicable building code.

It is generally advisable to perform full load tests and/or non-destructive material tests of the performer flying system at least annually by qualified person. Performer flying systems in continuous use should be tested more frequently.

The inspection interval can be changed if necessary by the Flying Safety Supervisor in consultation with the person responsible for the testing, considering the results of the risk assessment and the type and requirements of use. Relevant factors for changes might include the maintenance interval and the intensity of use. The Flying Safety Supervisor should document the rationale for changes.

A.7.10.3 Post Rescue Treatment of Flying Performers

If there is the danger of suspension trauma or orthostatic shock, medical personnel should be contacted immediately and informed of the hazard. If the person is not breathing or has no heartbeat, then immediate resuscitation should be performed in the horizontal position.